**BEFORE THE SOUTH DAKOTA PUBLIC UTILITIES COMMISSION**

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|---|---|
| IN THE MATTER OF THE APPLICATION BY CROWNED RIDGE WIND, LLC FOR A PERMIT OF A WIND ENERGY FACILITY IN GRANT AND CODINGTON COUNTIES | EL19-003<br><br>**INTERVENORS' EXHIBIT AND WITNESS LIST** |

COMES NOW, Intervenors and hereby submit their Exhibit and Witness List in preparation for the evidentiary hearing in the above captioned docket.

Intervenors provide this Exhibit and Witness List based upon the representations of the Applicant regarding Applicant's submitted Exhibit and Witness List. Exhibits and Witnesses as described in the Applicant's List which Intervenors assume for purposes of this proceeding will be used and called by Applicant at the hearing in this matter will be used and or called by Intervenors.

In addition Intervenors have previously submitted to the Commission Intervenor's Exhibits 1 through 7.

In addition, the following Exhibits are submitted:

**PUC Intervenors' Exhibit List**

| Description | ID |
|---|---|
| Public Service Commission of Wisconsin - A Cooperative Measurement Survey and Analysis of Low Frequency and Infrasound at the Shirley Wind Farm in Brown County, WI | **II Int-1** |

| | |
|---|---|
| NARUC - 2011 - Assessing Sound Emissions from Proposed Wind Farms & Measuring the Performance of Completed Projects | **I2**<br>**Int-2** |
| Paul Schomer, and Pranav Krishna Pamidighantam - A Possible Criterion for Wind Farms | **I3**<br>**Int-3** |
| Research Gate - Health Effects From Wind Turbine Low Frequency Noise & Infrasound: Do Wind Turbines Make People Sick? That is the Issue | **I4**<br>**Int-4** |
| David M. Hessler and George F. Hessler Jr. - Recommended Noise Level Design Goals and Limits at Residential Receptors for Wind Turbine Developments in the United States | **I5**<br>**Int-5** |
| David Hessler testimony Prevailing Winds proceeding | **I6**<br>**Int-6** |
| Institute of Noise Control Engineering INCE Code of Ethics | **I7**<br>**Int-7** |
| Night Time Noise Guidelines 2009 (WHO) | **I8**<br>**Int-8** |
| Ollson 2014 Suncor Statement (2 documents) | **I9A/I9B**<br>**Int-9A/9B** |
| Ollson 2014 Presentation | **I10**<br>**Int-10** |
| Thyen Exhibit A Memorandum 2007 | **I11**<br>**Int-11** |
| Thyen Exhibit B Release Letter 2012 | **I12**<br>**Int-12** |
| Thyen Exhibit C Sound Map 2019.5.24 | **I13**<br>**Int-13** |
| IAIA Assessment | **I14**<br>**Int-14** |
| Jay Haley Resume/DR to Intervenors 4-1 | **I15A/I15B**<br>**Int-15A/15B** |
| SD license search Mr. Haley | **I16**<br>**Int-16** |
| ND license search Mr. Haley | **I17A/I17B**<br>**Int-17A/17B** |
| MN license search Mr. Haley | **I18**<br>**Int-18** |
| MN license affidavit Mr. Haley | **I19**<br>**Int-19** |
| Mr. Haley Cover letter App H 1/22/19 | **I20**<br>**Int-20** |
| Mr. Haley Cover letter App I 1/22/19 | **I21**<br>**Int-21** |
| Mr. Haley Cover letter Updated Appendices Sound A-D 2/19/19 | **I22**<br>**Int-22** |
| Mr. Haley Cover letter Updated Appendices Flicker A-D 2/19/19 | **I23**<br>**Int-23** |
| Mr. Haley Cover letter Landowner Participation Sound 2/26/19 | **I24** |

| | |
|---|---|
| | **Int-24** |
| Mr. Haley Cover letter Landowner Participation Flicker 2/26/19 | **I25**<br>**Int-25** |
| Mr. Haley Cover letter Additional Structures Sound Ex 1 2/19/19 | **I26**<br>**I-26** |
| Mr. Haley Cover letter Additional Structures Flicker Ex 3 2/19/19 | **I27**<br>**I-27** |

Applicant reserves the right to introduce additional exhibits necessary to rebut evidence presented by any party in this docket or for impeachment and other legally permissible purposes.

Dated June 5, 2019

/s/ David L Ganje

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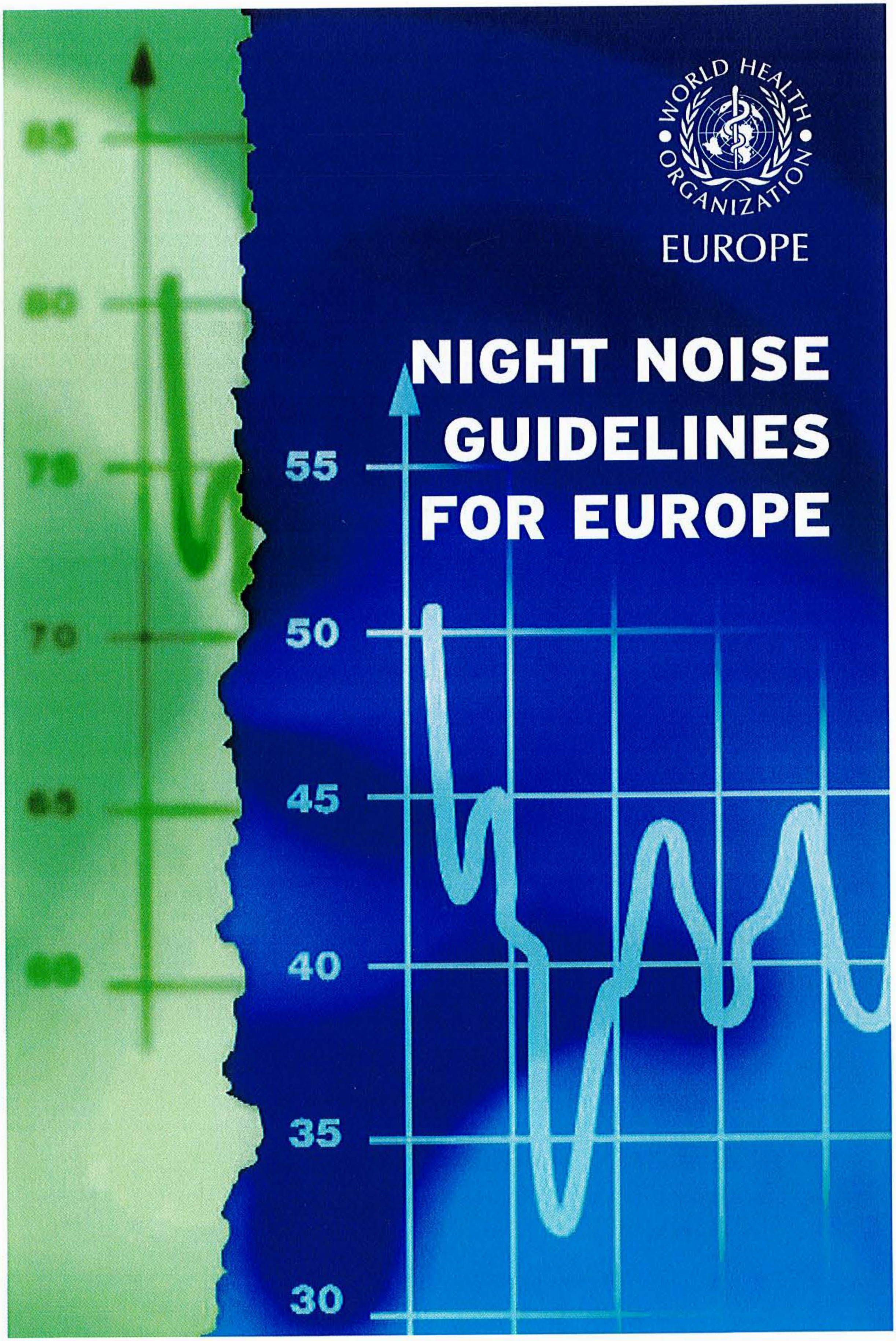
WORLD HEALTH ORGANIZATION
EUROPE
NIGHT NOISE GUIDELINES FOR EUROPE
55
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WORLD HEALTH ORGANIZATION
EUROPE

# NIGHT NOISE GUIDELINES FOR EUROPE

**Keywords**
**NOISE - ADVERSE EFFECTS - PREVENTION AND CONTROL**
**SLEEP DEPRIVATION - ETIOLOGY**
**SLEEP DISORDERS - PREVENTION AND CONTROL**
**ENVIRONMENTAL HEALTH**
**HEALTH POLICY - LEGISLATION**
**GUIDELINES**

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## CHAPTER 3 EFFECTS OF NIGHT-TIME NOISE ON SLEEP



## CHAPTER 4 EFFECTS OF NIGHT-TIME NOISE ON HEALTH AND WELL-BEING

# ABSTRACT

The WHO Regional Office for Europe set up a working group of experts to provide scientific advice to the Member States for the development of future legislation and policy action in the area of assessment and control of night noise exposure. The working group reviewed available scientific evidence on the health effects of night noise, and derived health-based guideline values. In December 2006, the working group and stakeholders from industry, government and nongovernmental organizations reviewed and reached general agreement on the guideline values and key texts for the final document of the *Night noise guidelines for Europe*.

Considering the scientific evidence on the thresholds of night noise exposure indicated by $L_{night,outside}$ as defined in the Environmental Noise Directive (2002/49/EC), an $L_{night,outside}$ of 40 dB should be the target of the night noise guideline (NNG) to protect the public, including the most vulnerable groups such as children, the chronically ill and the elderly. $L_{night,outside}$ value of 55 dB is recommended as an interim target for the countries where the NNG cannot be achieved in the short term for various reasons, and where policy-makers choose to adopt a stepwise approach. These guidelines are applicable to the Member States of the European Region, and may be considered as an extension to, as well as an update of, the previous WHO *Guidelines for community noise* (1999).

# FOREWORD



WHO defines health as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity, and recognizes the enjoyment of the highest attainable standard of health as one of the fundamental rights of every human being. Environmental noise is a threat to public health, having negative impacts on human health and well-being. In order to support the efforts of the Member States in protecting the population's health from the harmful levels of noise, WHO issued *Guidelines for community noise* in 1999, which includes guideline values for community noise in various settings based on the scientific evidence available. The evidence on health impacts of night noise has been accumulated since then.

In the WHO European Region, environmental noise emerged as the leading environmental nuisance triggering one of the most common public complaints in many Member States. The European Union tackled the problem of environmental noise with an international law on the assessment and management of environmental noise. The WHO Regional Office for Europe developed the *Night noise guidelines for Europe* to provide expertise and scientific advice to the Member States in developing future legislations in the area of night noise exposure control and surveillance, with the support of the European Commission. This guidelines document reviews the health effects of night time noise exposure, examines exposure-effects relations, and presents guideline values of night noise exposure to prevent harmful effects of night noise in Europe. Although these guidelines are neither standards nor legally binding criteria, they are designed to offer guidance in reducing the health impacts of night noise based on expert evaluation of scientific evidence in Europe.

The review of scientific evidence and the derivation of guideline values were conducted by outstanding scientists. The contents of the document were peer reviewed and discussed for a consensus among the experts and the stakeholders from industry, government and nongovernmental organizations. We at WHO are thankful for those who contributed to the development and presentation of this guidelines and believe that this work will contribute to improving the health of the people in the Region.

**Marc Danzon**
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# EXECUTIVE SUMMARY



## INTRODUCTION

The aim of this document is to present the conclusions of the WHO working group responsible for preparing guidelines for exposure to noise during sleep. This document can be seen as an extension of the WHO *Guidelines for community noise* (1999). The need for "health-based" guidelines originated in part from the European Union Directive 2002/49/EC relating to the assessment and management of environmental noise (commonly known as the Environmental Noise Directive and abbreviated as END) which compels European Union Member States to produce noise maps and data about night exposure from mid-2007. The work was made possible by a grant from the European Commission and contributions from the Swiss and German governments.

Although a number of countries do have legislation directed at controlling night noise exposure, there is little information on actual exposure and its subsequent effects on the population. Estimates made in some countries of the number of people highly disturbed by noise during sleep (see Fig. 1 for the Netherlands as an example) indicate that a substantial part of the population could be exposed to levels that might risk their health and well-being.

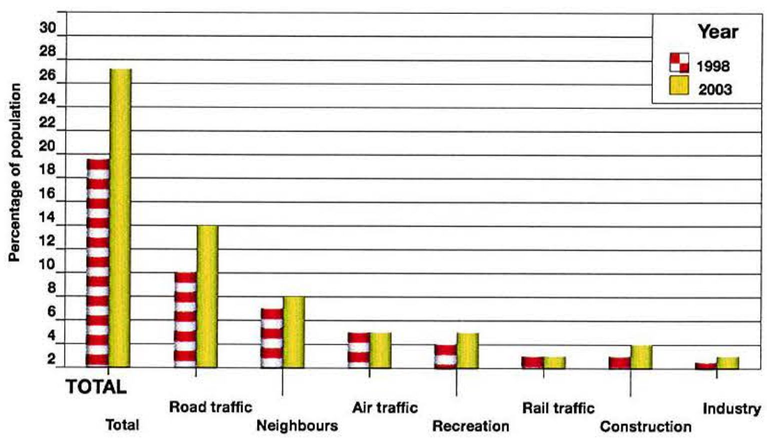



**Fig. 1. Percentage of population highly disturbed by noise during sleep in the Netherlands: survey results for 1998 and 2003**

As direct evidence concerning the effects of night noise on health is rarely available, these guidelines also use indirect evidence: the effects of noise on sleep and the relations between sleep and health. The advantage of this approach is that a lot of medical evidence is available on the relation between sleep and health, and detailed information also exists on sleep disturbance by noise.

## PROCESS OF DEVELOPING GUIDELINES

In 2003, the WHO Regional Office for Europe set up a working group of experts to provide scientific advice to the European Commission and to its Member States for the development of future legislation and policy action in the area of control and surveillance of night noise exposure. The review of available scientific evidence on the health effects of night noise was carried out by an interdisciplinary team who set out to derive health-based guideline values. The contributions from the experts were reviewed by the team and integrated into draft reports following discussion at four technical meetings of the working group. In 2006, all the draft reports were compiled into a draft document on guidelines for exposure to noise at night, which was reviewed and commented on by a number of stakeholders and experts.

At the final conference in Bonn, Germany, on 14 December 2006, representatives from the working group and stakeholders from industry, government and non-governmental organizations reviewed the contents of the draft document chapter by chapter, discussed several fundamental issues and reached general agreement on the guideline values and related texts to be presented as conclusions of the final WHO *Night noise guidelines for Europe*.

## NOISE INDICATORS

From the scientific point of view the best criterion for choosing a noise indicator is its ability to predict an effect. Therefore, for different health end points, different indicators could be chosen. Long-term effects such as cardiovascular disorders are more correlated with indicators summarizing the acoustic situation over a long time period, such as yearly average of night noise level outside at the facade ($L_{night,outside}$)[1], while instantaneous effects such as sleep disturbance are better with the maximum level per event ($L_{Amax}$), such as passage of a lorry, aeroplane or train.

From a practical point of view, indicators should be easy to explain to the public so that they can be understood intuitively. Indicators should be consistent with existing practices in the legislation to enable quick and easy application and enforcement. $L_{night,outside}$, adopted by the END, is an indicator of choice for both scientific and practical use. Among currently used indicators for regulatory purposes, $L_{Aeq}$ (A-weighted equivalent sound pressure level) and $L_{Amax}$ are useful to predict short-term or instantaneous health effects.

## SLEEP TIME

Time use studies, such as that undertaken by the Centre for Time Use Research, 2006 (www.timeuse.org/access/), show that the average time adult people are in bed is around 7.5 hours, so the real average sleeping time is somewhat shorter. Due to personal factors like age and genetic make-up there is considerable variation in sleeping time and in beginning and end times. For these reasons, a fixed interval of 8 hours is a minimal choice for night protection.

Though results vary from one country to another, data show (see Fig. 2 as an example) that an 8-hour interval protects around 50% of the population and that it would take a period of 10 hours to protect 80%. On Sundays, sleeping time is consistently 1 hour longer, probably due to people recovering from sleep debt incurred during the week. It should also be borne in mind that (young) children have longer sleeping times.

[1] $L_{night}$ is defined in the END as the outside level. In order to avoid any doubt, the suffix "outside" is added in this document.

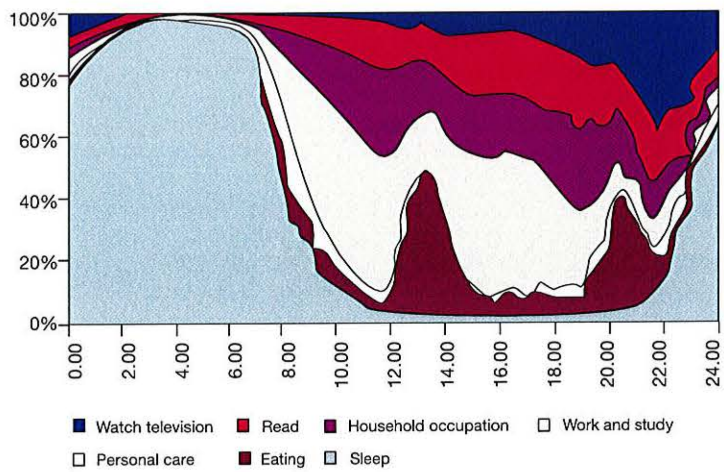



**Fig. 2 Percentage of time that the Portuguese population spend asleep or in different activities**

*Source: http://www.ine.pt/prodserv/destaque/arquivo.asp, based on a study by the Instituto Nacional de Estatistica Portugal, 1999.*

## NOISE, SLEEP AND HEALTH

There is plenty of evidence that sleep is a biological necessity, and disturbed sleep is associated with a number of health problems. Studies of sleep disturbance in children and in shift workers clearly show the adverse effects.

Noise disturbs sleep by a number of direct and indirect pathways. Even at very low levels physiological reactions (increase in heart rate, body movements and arousals) can be reliably measured. Also, it was shown that awakening reactions are relatively rare, occurring at a much higher level than the physiological reactions.

### DEFINITION OF "SUFFICIENT" AND "LIMITED" EVIDENCE

Sufficient evidence: A causal relation has been established between exposure to night noise and a health effect. In studies where coincidence, bias and distortion could reasonably be excluded, the relation could be observed. The biological plausibility of the noise leading to the health effect is also well established.

Limited evidence: A relation between the noise and the health effect has not been observed directly, but there is available evidence of good quality supporting the causal association. Indirect evidence is often abundant, linking noise exposure to an intermediate effect of physiological changes which lead to the adverse health effects.

The working group agreed that there is sufficient evidence that night noise is related to self-reported sleep disturbance, use of pharmaceuticals, self-reported health problems and insomnia-like symptoms. These effects can lead to a considerable burden of disease in the population. For other effects (hypertension, myocardial infarctions, depression and others), limited evidence was found: although the studies were few or not conclusive, a biologically plausible pathway could be constructed from the evidence.

An example of a health effect with limited evidence is myocardial infarction. Although evidence for increased risk of myocardial infarction related to $L_{day}$ is sufficient according to an updated meta-analysis, the evidence in relation to $L_{night,outside}$ was considered limited. This is because $L_{night,outside}$ is a relatively new exposure indicator, and few field studies have focused on night noise when considering cardiovascular outcomes. Nevertheless, there is evidence from animal and human studies supporting a hypothesis that night noise exposure might be more strongly associated with cardiovascular effects than daytime exposure, highlighting the need for future epidemiological studies on this topic.

The review of available evidence leads to the following conclusions.

- Sleep is a biological necessity and disturbed sleep is associated with a number of adverse impacts on health.
- There is sufficient evidence for biological effects of noise during sleep: increase in heart rate, arousals, sleep stage changes and awakening.
- There is sufficient evidence that night noise exposure causes self-reported sleep disturbance, increase in medicine use, increase in body movements and (environmental) insomnia.
- While noise-induced sleep disturbance is viewed as a health problem in itself (environmental insomnia), it also leads to further consequences for health and well-being.
- There is limited evidence that disturbed sleep causes fatigue, accidents and reduced performance.
- There is limited evidence that noise at night causes hormone level changes and clinical conditions such as cardiovascular illness, depression and other mental illness. It should be stressed that a plausible biological model is available with sufficient evidence for the elements of the causal chain.

## VULNERABLE GROUPS

Children have a higher awakening threshold than adults and therefore are often seen to be less sensitive to night noise. For other effects, however, children seem to be equally or more reactive than adults. As children also spend more time in bed they are exposed more to night noise levels. For these reasons children are considered a risk group.

Since with age the sleep structure becomes more fragmented, elderly people are more vulnerable to disturbance. This also happens in pregnant women and people with ill health, so they too are a group at risk.

Finally, shift workers are at risk because their sleep structure is under stress due to the adaptations of their circadian rhythm.

## THRESHOLDS FOR OBSERVED EFFECTS

The no observed adverse effect level (NOAEL) is a concept from toxicology, and is defined as the greatest concentration which causes no detectable adverse alteration of morphology, functional capacity, growth, development or lifespan of the target organism. For the topic of night noise (where the adversity of effects is not always clear) this concept is less useful. Instead, the observed effect thresholds are provided: the level above which an effect starts to occur or shows itself to be dependent on the exposure level. It can also be a serious pathological effect, such as myocardial infarctions, or a changed physiological effect, such as increased body movement.

Threshold levels of noise exposure are important milestones in the process of evaluating the health consequences of environmental exposure. The threshold levels also delimit the study area, which may lead to a better insight into overall consequences. In Tables 1 and 2, all effects are summarized for which *sufficient and limited evidence* exists. For these effects, the threshold levels are usually well known, and for some the dose-effect relations over a range of exposures could also be established.

**Table 1**
**Summary of effects and threshold levels for effects where *sufficient* evidence is available**

| Effect | | Indicator | Threshold, dB |
|---|---|---|---|
| Biological effects | Change in cardiovascular activity | * | * |
| | EEG awakening | $L_{Amax,inside}$ | 35 |
| | Motility, onset of motility | $L_{Amax,inside}$ | 32 |
| | Changes in duration of various stages of sleep, in sleep structure and fragmentation of sleep | $L_{Amax,inside}$ | 35 |
| Sleep quality | Waking up in the night and/or too early in the morning | $L_{Amax,inside}$ | 42 |
| | Prolongation of the sleep inception period, difficulty getting to sleep | * | * |
| | Sleep fragmentation, reduced sleeping time | * | * |
| | Increased average motility when sleeping | $L_{night,outside}$ | 42 |
| Well-being | Self-reported sleep disturbance | $L_{night,outside}$ | 42 |
| | Use of somnifacient drugs and sedatives | $L_{night,outside}$ | 40 |
| Medical conditions | Environmental insomnia** | $L_{night,outside}$ | 42 |

* *Although the effect has been shown to occur or a plausible biological pathway could be constructed, indicators or threshold levels could not be determined.*

***Note that "environmental insomnia" is the result of diagnosis by a medical professional whilst "self-reported sleep disturbance" is essentially the same, but reported in the context of a social survey. Number of questions and exact wording may differ.*

**Table 2 Summary of effects and threshold levels for effects where *limited* evidence is available****

| Effect | | Indicator | Estimated threshold, dB |
|---|---|---|---|
| Biological effects | Changes in (stress) hormone levels | * | * |
| Well-being | Drowsiness/tiredness during the day and evening | * | * |
| | Increased daytime irritability | * | * |
| | Impaired social contacts | * | * |
| | Complaints | $L_{night,outside}$ | 35 |
| Medical conditions | Impaired cognitive performance | * | * |
| | Insomnia | * | * |
| | Hypertension | $L_{night,outside}$ | 50 |
| | Obesity | * | * |
| | Depression (in women) | * | * |
| | Myocardial infarction | $L_{night,outside}$ | 50 |
| | Reduction in life expectancy (premature mortality) | * | * |
| | Psychic disorders | $L_{night,outside}$ | 60 |
| | (Occupational) accidents | * | * |

* *Although the effect has been shown to occur or a plausible biological pathway could be constructed, indicators or threshold levels could not be determined.*
** *Note that as the evidence for the effects in this table is limited, the threshold levels also have a limited weight. In general they are based on expert judgement of the evidence.*

## RELATIONS WITH $L_{NIGHT,OUTSIDE}$

Over the next few years, the END will require that night 'noise' exposures are reported in $L_{night,outside}$. It is, therefore, interesting to look into the relation between $L_{night,outside}$ and adverse health effects. The relation between the effects and $L_{night,outside}$ is, however, not straightforward. Short-term effects are mainly related to maximum levels per event inside the bedroom: $L_{Amax,inside}$. In order to express the (expected) effects in relation to the single European Union indicator, some calculation needs to be done. The calculation for the total number of effects from reaction data on events (arousals, body movements and awakenings) needs a number of assumptions. The first that needs to be made is independence: although there is evidence that the order of events of different loudness strongly influences the reactions, the calculation is nearly impossible to carry out if this is taken into consideration. Secondly, the reactions per event are known in relation to levels at the ear of the sleeper, so an assumption for an average insulation value must be made. In the report a value of 21 dB has been selected. This value is, however, subject to national and cultural differences. One thing that stands out is the desire of a large part of the population to sleep with windows (slightly) open. The relatively low value of 21 dB takes this into account already. If noise levels increase, people do indeed close their windows, but obviously reluctantly, as complaints about bad air then increase and sleep disturbance remains high. This was already pointed out in the WHO *Guidelines for community noise* (1999).

From source to source the number of separate events varies considerably. Road traffic noise is characterized by relatively low levels per event and high numbers, while air and rail traffic are characterized by high levels per event and low numbers. For two typical situations estimates have been made and presented in graphical form. The first is an average urban road (600 motor vehicles per night, which corresponds roughly to a 24-hour use of 8000 motor vehicles, or 3 million per year, the lower boundary the END sets) and the second case is for an average situation of air traffic exposure (8 flights per night, nearly 3000 per year).

Fig. 3 shows how effects increase with an increase of $L_{night,outside}$ values for the typical road traffic situation (urban road). A large number of events lead to high levels of awakening once the threshold of $L_{Amax,inside}$ is exceeded. To illustrate this in practical terms: values over 60 dB $L_{night,outside}$ occur at less then 5 metres from the centre of the road.

In Fig. 4 the same graph is presented for the typical airport situation. Due to a lower number of events there are fewer awakenings than in the road traffic case (Fig. 3), but the same or more health effects. In these examples the worst case figures can be factors higher: the maximum number of awakenings for an $L_{night,outside}$ of 60–65 dB is around 300 per year.

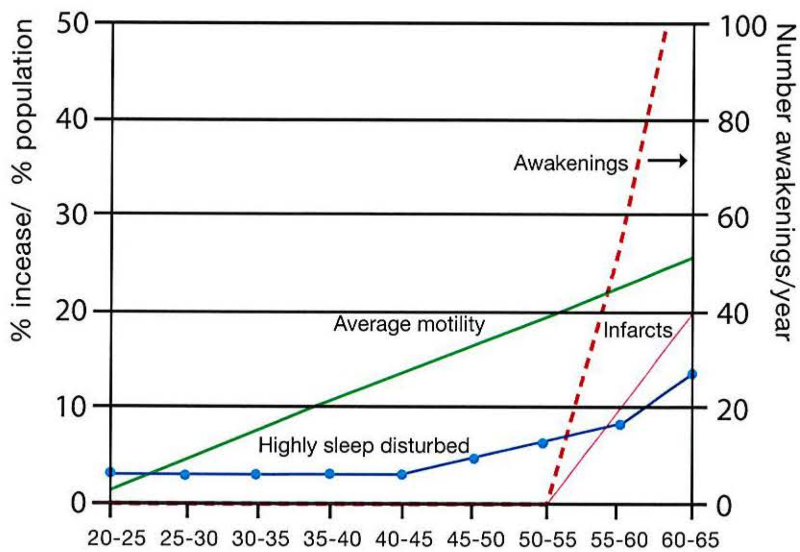



**Fig. 3 Effects of road traffic noise at night***

**Average motility and infarcts are expressed in percent increase (compared to baseline number); the number of highly sleep disturbed people is expressed as a percent of the population; awakenings are expressed in number of additional awakenings per year.*

A recent study suggests that high background levels of noise (from motorways) with a low number of separate events can cause high levels of average motility.

Therefore, by using the $L_{night,outside}$ as a single indicator, a relation between effects and indicator can be established. For some effects, however, the relation can be

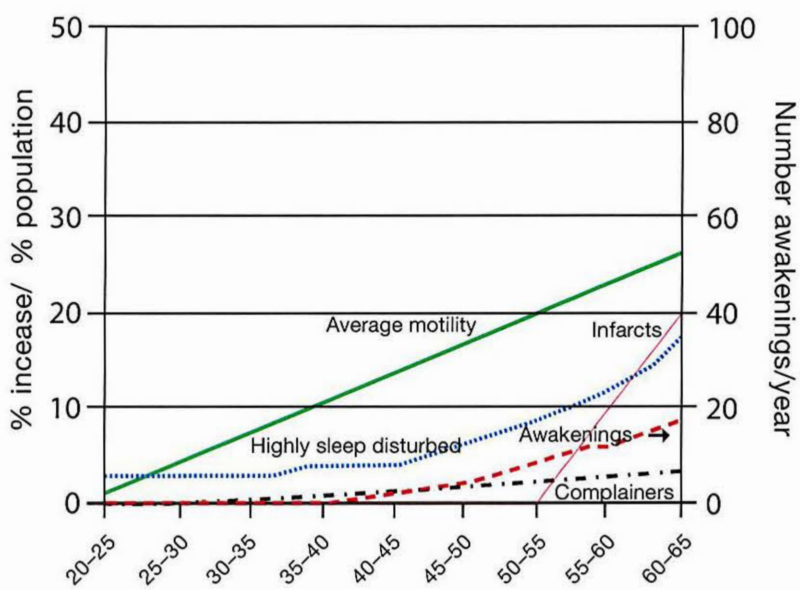



**Fig. 4**
**Effects of aircraft noise at night***

**Average motility and infarcts are expressed in percent increase (compared to baseline number); the number of highly sleep disturbed people is expressed as a percent of the population; complainers are expressed as a % of the neighbourhood population; awakenings are expressed in number of additional awakenings per year.*

source dependent. Although $L_{night}$ gives a good relation for most effects, there is a difference between sources for some. Train noise gives fewer awakenings, for instance. Once source is accounted for, the relations are reasonably accurate.

## RECOMMENDATIONS FOR HEALTH PROTECTION

Based on the systematic review of evidence produced by epidemiological and experimental studies, the relationship between night noise exposure and health effects can be summarized as below. (Table 3)

Below the level of 30 dB $L_{night, outside}$, no effects on sleep are observed except for a slight increase in the frequency of body movements during sleep due to night noise. There is no sufficient evidence that the biological effects observed at the level below 40 dB $L_{night, outside}$ are harmful to health. However, adverse health effects are observed at the level above 40 dB $L_{night, outside}$, such as self-reported sleep disturbance, environmental insomnia, and increased use of somnifacient drugs and sedatives.

Therefore, 40 dB $L_{night, outside}$ is equivalent to the lowest observed adverse effect level (LOAEL) for night noise. Above 55 dB the cardiovascular effects become the major public health concern, which are likely to be less dependent on the nature of the noise. Closer examination of the precise impact will be necessary in the range between 30 dB and 55 dB as much will depend on the detailed circumstances of each case.

**Table 3**
**Effects of different levels of night noise on the population's health**

| Average night noise level over a year $L_{night,outside}$ | Health effects observed in the population |
|---|---|
| Up to 30 dB | Although individual sensitivities and circumstances may differ, it appears that up to this level no substantial biological effects are observed. $L_{night,outside}$ of 30 dB is equivalent to the no observed effect level (NOEL) for night noise. |
| 30 to 40 dB | A number of effects on sleep are observed from this range: body movements, awakening, self-reported sleep disturbance, arousals. The intensity of the effect depends on the nature of the source and the number of events. Vulnerable groups (for example children, the chronically ill and the elderly) are more susceptible. However, even in the worst cases the effects seem modest. $L_{night,outside}$ of 40 dB is equivalent to the lowest observed adverse effect level (LOAEL) for night noise. |
| 40 to 55 dB | Adverse health effects are observed among the exposed population. Many people have to adapt their lives to cope with the noise at night. Vulnerable groups are more severely affected. |
| Above 55 dB | The situation is considered increasingly dangerous for public health. Adverse health effects occur frequently, a sizeable proportion of the population is highly annoyed and sleep-disturbed. There is evidence that the risk of cardiovascular disease increases. |

A number of instantaneous effects are connected to threshold levels expressed in $L_{Amax}$. The health relevance of these effects cannot be easily established. It can be safely assumed, however, that an increase in the number of such events over the baseline may constitute a subclinical adverse health effect by itself leading to significant clinical health outcomes.

Based on the exposure-effects relationship summarized in Table 3, the night noise guideline values are recommended for the protection of public health from night noise as below.

**Table 4**
**Recommended night noise guidelines for Europe**

| | |
|---|---|
| Night noise guideline (NNG) | $L_{night,outside} = 40$ dB |
| Interim target (IT) | $L_{night,outside} = 55$ dB |

[1] $L_{night,outside}$ is the night-time noise indicator ($L_{night}$) of Directive 2002/49/EC of 25 June 2002: the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year; in which: the night is eight hours (usually 23.00 – 07.00 local time), a year is a relevant year as regards the emission of sound and an average year as regards the meteorological circumstances, the incident sound is considered, the assessment point is the same as for $L_{den}$. See *Official Journal of the European Communities*, 18.7.2002, for more details.

For the primary prevention of subclinical adverse health effects related to night noise in the population, it is recommended that the population should not be exposed to night noise levels greater than 40 dB of $L_{night,outside}$ during the part of the night when most people are in bed. The LOAEL of night noise, 40 dB $L_{night,outside}$, can be considered a health-based limit value of the night noise guidelines (NNG) necessary to protect the public, including most of the vulnerable groups such as children, the chronically ill and the elderly, from the adverse health effects of night noise.

An interim target (IT) of 55 dB $L_{night,outside}$ is recommended in the situations where the achievement of NNG is not feasible in the short run for various reasons. It should be emphasized that IT is not a health-based limit value by itself. Vulnerable groups cannot be protected at this level. Therefore, IT should be considered only as a feasibility-based intermediate target which can be temporarily considered by policy-makers for exceptional local situations.

## RELATION WITH THE GUIDELINES FOR COMMUNITY NOISE (1999)

Impact of night-time exposure to noise and sleep disturbance is indeed covered in the 1999 guidelines, as below (WHO, 1999):

> "If negative effects on sleep are to be avoided the equivalent sound pressure level should not exceed 30 dBA indoors for continuous noise. If the noise is not continuous, sleep disturbance correlates best with $L_{Amax}$ and effects have been observed at 45 dB or less. This is particularly true if the background level is low. Noise events exceeding 45 dBA should therefore be limited if possible. For sensitive people an even lower limit would be preferred. It should be noted that it should be possible to sleep with a bedroom window slightly open (a reduction from outside to inside of 15 dB). To prevent sleep disturbances, one should thus consider the equivalent sound pressure level and the number and level of sound events. Mitigation targeted to the first part of the night is believed to be effective for the ability to fall asleep."

The 1999 guidelines are based on studies carried out up to 1995 (and a few meta-analyses some years later). Important new studies (Passchier-Vermeer et al., 2002; Basner et al., 2004) have become available since then, together with new insights into normal and disturbed sleep. New information has made more precise assessment of exposure-effect relationship. The thresholds are now known to be lower than $L_{Amax}$ of 45 dB for a number of effects. The last three sentences still stand: there are good reasons for people to sleep with their windows open, and to prevent sleep disturbances one should consider the equivalent sound pressure level and the number of sound events. The present guidelines allow responsible authorities and stakeholders to do this. Viewed in this way, the *night noise guidelines for Europe* are complementary to the 1999 guidelines. This means that the recommendations on government policy framework on noise management elaborated in the 1999 guidelines should be considered valid and relevant for the Member States to achieve the guideline values of this document.

# CHAPTER 1

# INTRODUCTION: METHODS AND CRITERIA

*With regard to sleep and waking, we must consider what they are: whether they are peculiar to soul or to body, or common to both; and if common, to what part of soul or body they appertain: further, from what cause it arises that they are attributes of animals, and whether all animals share in them both, or some partake of the one only, others of the other only, or some partake of neither and some of both.*

*(Aristotle, On sleep and sleeplessness, 350 BC)*

## 1.1 INTRODUCTION

### 1.1.1 EXISTING POLICY DOCUMENTS FOR NIGHT-TIME NOISE

The aim of this document is to present guidance for exposure to noise during sleep. What is already available?

There are three related documents at the international level:

- *Guidelines for community noise* (WHO, 1999)
- *Directive 2002/49/EC relating to the assessment and management of environmental noise* (European Commission, 2002b)
- *Position Paper on dose-effect relationships for night-time noise* (European Commission, 2004).

In Chapter 5 the relation with the *Guidelines for community noise* (1999) will be explained.

The European Union (EU) Directive relating to the assessment and management of environmental noise (or, as it is commonly known, the Environmental Noise Directive – END), establishes that Member States should create noise maps (2007) and action plans (2008) for parts of their territory. The noise maps should present noise levels expressed in the harmonized indicators $L_{den}$ and $L_{night}$. Although in the first round only between 20% and 30% of the population will be covered, it is expected that through the use of harmonized methods and indicators a deeper insight will be gained into the exposure of the population to noise. The END does not, however, set any limit values: on the basis of the subsidiarity principle this is left to the Member States. The Directive does, however, require Member States to report on their limit values and express them in the standard indicators. On the CIRCA web site (Communication and Information Resource Centre Administrator, European Commission, 2006) an overview of the data reported to the Commission can be found. Out of the 25 Member States, 10 reported on the $L_{night}$ limits. In Table 1.1 some of these data are summarized.

Due to differences in legal systems it is hard to predict what the actual effect of a certain limit value will be. It could be a relatively high value but rigidly enforced, or a very low value with no legal binding whatsoever.

The *Position Paper* on dose-effect relationships for night-time noise is foreseen in the END (Annex III) and aims to give the competent authorities a tool to evaluate the impact on the population. However, it neither provides limit values nor guidelines. The same information that was used in the *Position Paper* also plays a role in these guidelines.

**Table 1.1**
**Reported $L_{night}$ limit values for road traffic noise in new residential areas**

| EU Member State | $L_{night,outside}$ |
|---|---|
| France | 62 |
| Germany | 49 |
| Spain | 45 |
| Netherlands | 40 |
| Austria | 50 |
| Sweden | 51 (converted from $L_{Aeq}$ limit 30 dB(A) inside bedroom) |
| Finland | 46 |
| Hungary | 55 |
| Latvia | 40 |
| Estonia | 45 |
| Switzerland | 50 |

*Source: European Commission, 2006.*

### 1.1.2 GENERAL MODEL

There is no doubt that a relation exists between sleep and health and well-being, as most of us know from personal experience. That does not mean, however, that this relation is simple. People who do not sleep well may not feel well the day after, but the reverse is also true: unfit people may have a disturbed sleep. Untangling the relations between health and disturbed sleep (night-time noise is only one of many causes) proved difficult, and Fig. 2.1 at the end of Chapter 2 shows why.

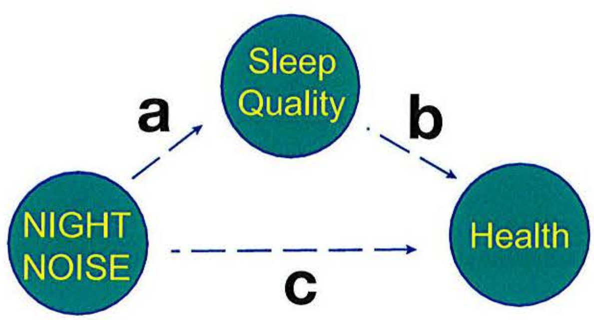



**Fig. 1.1.**
**General structure of the report on the effects of night noise**

The general structure of the report is given in Fig. 1.1: evidence for the effects of night-time noise on health (c) is supported by evidence on the indirect route via (a) and (b). In Chapter 2 the relations between sleep and health are examined (relation (b) in Fig. 1.1), and this involves clinical evidence from sleep laboratories, but also evidence from animal experiments. In Chapter 3 it is shown how noise disturbs sleep from the basic, autonomous level up to conscious awakenings: relation (a). Chapter 4 presents the evidence between night-time noise and health and well-being: relation (c) in Fig. 1.1. The last chapter, Chapter 5, then provides guidance on reducing health impacts caused by night-time noise exposure.

## 1.1.3 PROCESS OF DEVELOPING GUIDELINES

The WHO Regional Office for Europe started the night noise guidelines (NNGL) project with a grant from the European Commission's Directorate-General for Health and Consumer Affairs. In 2003, the WHO Regional Office for Europe set up a working group of experts to provide scientific advice for the development of guidelines for future legislation and policy action in the area of control and surveillance of night noise exposure. The review of available scientific evidence on the health effects of night noise was carried out by the working group to derive health-based guideline values. The contributions from the experts were reviewed by the team and integrated into draft reports following discussion at four technical meetings of the working group.

The first meeting of the working group was held in Bonn, June 2004. It was agreed that the experts would produce background papers on a number of topics identified and assigned at the meeting.

The second meeting in Geneva, December 2004, concentrated on such technical issues as exposure assessment, metrics, health effects and guideline set-up. The topic-specific experts presented the first drafts for the identified topics for detailed discussions at the meeting. The discussions concentrated on central issues such as exposure assessment and guideline derivation.

The third meeting in Lisbon, April 2005, reviewed the revised background papers, and discussed in detail the overall structure of the guidelines document, and the process of consensus building among the working group and stakeholders.

At the workshop of acoustics experts in The Hague, September 2005, a consensus was made on the use of $L_{night}$ as the single indicator for guideline values as it effectively combines the information on the number of events and the maximum sound levels per event over a year.

In 2006, all the draft reports collected at previous meetings were compiled by Mr. Martin van den Berg into a coherent document on guidelines for exposure to noise at night. The latter was revised according to the comments collected though a peer-review by the working group experts.

At the concluding meeting in Bonn, December 2006, the working group and stakeholders from industry, government and nongovernmental organizations reviewed the contents of the draft document chapter by chapter, discussed several fundamental issues and reached general consensus on the guideline values. The final implementation report of NNGL project was submitted to the EU in early 2007.

The following countries and institutes contributed to the development of *Night noise guidelines for Europe* as project partners.

| | |
|---|---|
| AUSTRIA: | Institute of Hygiene and Social Medicine, University of Innsbruck |
| CZECH REPUBLIC: | Charles University in Prague |
| DENMARK: | National Institute of Public Health |
| FRANCE: | INRETS/LTE – Laboratoire Transports et Environnement<br>CNRS – Centre National de Recherche Scientifique |
| GERMANY: | Umweltbundesamt – Federal Environmental Agency<br>Landesgesundheitsamt Baden-Württemberg |

| | |
|---|---|
| ITALY: | ARPAT–Environmental Protection Agency, Tuscany Region |
| | University of Rome "La Sapienza"– Center for Pediatric Sleep Disorders |
| NETHERLANDS: | TNO–Netherlands Organisation for Applied Scientific Research |
| | RIVM–National Institute of Public Health and the Environment |
| POLAND: | University of Warsaw, Clinic of Psychiatry of the Medical Academy |
| PORTUGAL: | IST–Instituto Superior Técnico |
| SLOVENIA: | Institute of Public Health of the Republic of Slovenia |
| SWEDEN: | University of Gävle, Centre for Built Environment |
| UNITED KINGDOM: | Queen Mary and Westfield College, University of London |

In addition, WHO received advice and support from a number of national experts who participated in the working group. The affiliations of these additional expert advisers include:

| | |
|---|---|
| CANADA: | Health Canada |
| GERMANY: | Forschungs- und Beratungsbüro Maschke |
| SWITZERLAND: | Bundesamt für Umwelt, Wald und Landschaft |
| | Universität St. Gallen, Institut für Wirtschaft und Ökologie |
| NETHERLANDS: | Ministry of Housing, Spatial Planning and Environment |
| UNITED KINGDOM: | Casella Stanger Environmental Consultants |

Since the project report was published on the EU web site, various comments were received from experts who have not participated in the working group. The most critical points were regarding the achievability of guideline values in practice. Responding to these feedbacks, the WHO Regional Office for Europe, prepared a revision of guidelines and recommendations, and consulted with international experts and stakeholders including the EU. As of late 2008, it was agreed that the guideline should be based on the lowest observed adverse effects level (LOAEL) rather than the no observed effects level (NOEL). Interim target was also introduced as a feasibility-based level.

## 1.2 STRENGTH OF EVIDENCE

### 1.2.1 BASIC CONCEPTS

This document uses well-established practices from other disciplines and policy fields. Of main interest here are evidence-based medicine, the use of epidemiological evidence for environmental risk assessment and experiences with – principally– air quality guidelines.

The concept of "evidence" is further formalized, as variations in wording and scope are currently in use.

## 1.2.2 RISK ASSESSMENT AND RISK CONTROL

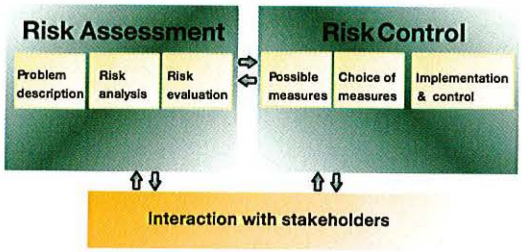



**Fig. 1.2**
**Elements of risk control**

*Source:*
*Health Council of the Netherlands, 2004.*

Fig. 1.2 outlines a general approach for risk assessment and control. This approach consists of the following steps:

1. problem description: assessing the impact on the population
2. risk analysis: evaluation of impact
3. risk evaluation: assessing impact considered undesirable
4. assessment of options to avoid or reduce impact
5. cost–benefit analysis of the options or of the mix of options
6. assessment of the preferred option
7. implementation and control.

It is important to observe that guideline values can be an input to, as well as an output of this process. At lower levels of decision (a particular infrastructure project, for instance) a preset guideline value reduces – intentionally – the degrees of freedom in the process. At the highest national or international level a guideline value is the outcome. As the scope of this document is to present the health consequences of night-time noise exposure (and not so much the economic outcomes of the choice of a certain value) it concentrates on the first three elements in the risk assessment block.

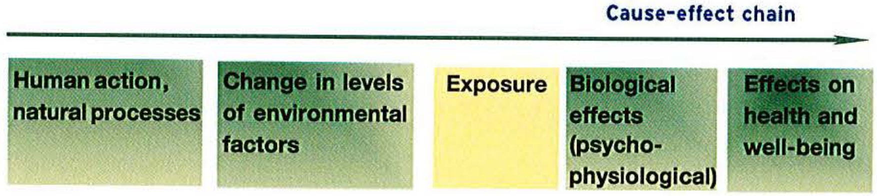
The following questions need to be addressed.

- What is the strength of the available evidence – what are the uncertainties?
- What is the health significance for the effects found?
- How serious is the impact on health?
- Does every instance of exposure lead to an effect and how are they related?
- How can the number of affected people be established?

## 1.2.3 CAUSE–EFFECT CHAIN

Underlying this approach is the notion of a cause–effect chain between environmental factors and health, symbolically simplified in Fig. 1.3.

**Fig. 1.3**
**Cause-effect chain**




*Source: Health Council of the Netherlands, 2004.*

There are important questions that need to be asked.

- Is there a causal relation between one link in the chain and the next?
- What are the intervening factors in that relation?
- How strong is the evidence for the relations?

The last question is the hardest to answer, as "strength of evidence" is not easy to express in simple numbers or labels. There are two forms of uncertainty: uncertainty because of variability of outcomes and uncertainty due to a lack of knowledge.

For the purpose of this document the following classification will be used, largely based on the IARC (International Agency for Research on Cancer) criteria accessible at http://monographs.iarc.fr/ENG/Preamble/currentb6evalrationale0706.php (see Table 1.2).

**Table 1.2 Classification of evidence**

| Grade of evidence | Criteria |
|---|---|
| Sufficient evidence | A causal relation has been established between exposure to night-time noise and an effect. In studies where coincidence, bias and distortion could reasonably be excluded, the relation could be observed and it is plausible that the effect is (also) caused by the exposure. |
| Limited evidence | A relation was observed between exposure to night-time noise and an effect in studies where coincidence, bias and distortion could not reasonably be excluded. The relation is, however, plausible.<br>A direct relation between cause and effect has not been observed, but there is indirect evidence of good quality and the relation is plausible. Indirect evidence is assumed if exposure leads to an intermediate effect and other studies prove that the intermediate effect leads to the effect. |
| Insufficient evidence | Available studies are of low quality and lack significance to allow conclusions about causality of the relation between exposure and effect. Plausibility of the relation is limited or absent. |

## 1.2.4 PROCEDURE FOR DERIVING GUIDELINES

The following procedure was followed in order to derive an ordering of guideline values:

1. collection of relevant data
2. evaluation of data in terms of strength of evidence
3. evaluation of data in terms of biological effects, health and well-being
4. ranking of guideline values.

This procedure is essentially the same as in other guideline documents, although steps are more explicitly formalized. A major difference is that sound is a natural environmental quality, which makes defining a no-effect level a futile exercise. Therefore the choice was made for a series of levels with increasing severity of effects.



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# 1.3 CONSIDERATIONS WITH REGARD TO NIGHT-TIME NOISE INDICATORS

Briefly, the fundamental choices of night-time noise indicators with respect to length of night, use of single event descriptors and long-term average are commented on to assist the reader in understanding the relations presented in later chapters.

## 1.3.1 LENGTH OF NIGHT

Time use studies (Centre for Time Use Research, 2006) show that the average time adult people are in bed is around 7.5 hours, so the real average sleeping time is somewhat shorter. Due to personal factors such as age and genetic factors there is considerable variation in sleeping time and in beginning and end times. For these reasons, a fixed interval of 8 hours is a minimal choice for night-time protection. From Fig. 1.4 it can be noted that around 50% of the population is protected with an interval of 8 hours and it would take a period of 10 hours to protect 80%. On Sundays, sleeping time is consistently one hour longer, probably due to people recovering from sleep debt incurred during the week. Data for other countries are readily available but this is the only study covering a long period in a consistent way. Fig. 1.5 (from a time use study in Portugal) shows that the stable pattern found in the Netherlands (Fig. 1.4) is not only typical for northern Europe, but also for the southern part. The pattern, however, seems to have shifted slightly. These figures stress that sleep times might be biologically fixed in humans, and culture has almost no influence.

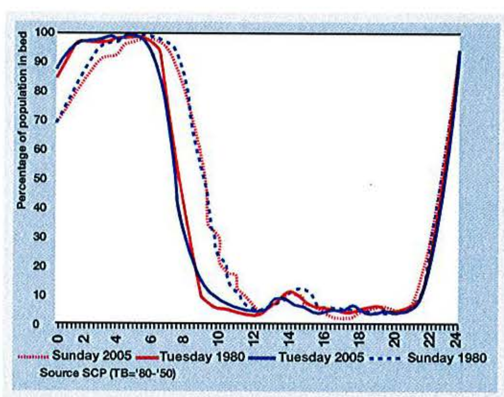


**Fig. 1.4**
**Sleep pattern of Dutch population on weekdays and Sundays, 1980-2005**

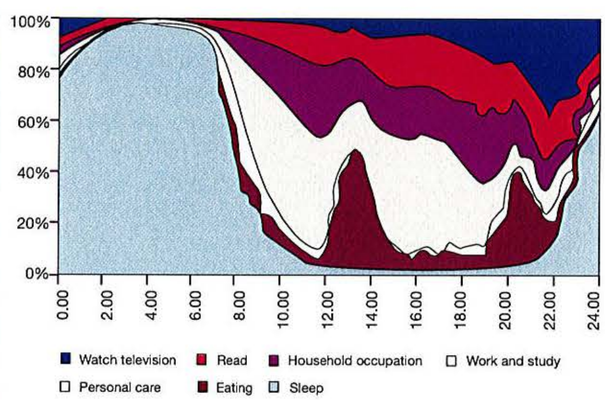


**Fig. 1.5**
**Percentage of time that the Portuguese population spend asleep or in different activities**

*Source: http://www.ine.pt/prodserv/destaque/arquivo.asp, based on a study by the Instituto Nacional de Estatistica Portugal, 1999*

## 1.3.2 EVENT OR LONG-TERM DESCRIPTOR

Much attention has been paid to the use of single event descriptors such as $L_{Amax}$ (maximum outdoor sound pressure level) and SEL (sound exposure level). As the *Position Paper* on EU noise indicators (European Commission, 2000) points out, this is an important laboratory tool to describe instantaneous reactions to noise. But when it comes to long-term protection, the number of events is equally important. The possibility of predicting after-effects like sleepiness, reaction time, sleeping pill



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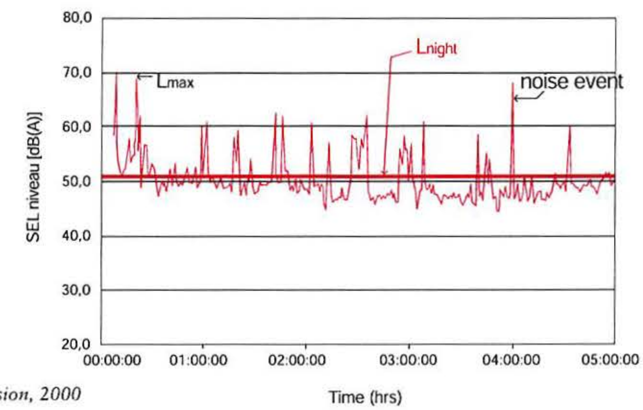
use and health complaints, in particular, requires a combination of a number of events and their level instead of just the average $L_{Amax}$ or average SEL. For events with a similar time pattern there is a relatively simple relation between $L_{Amax}$ and SEL, and therefore between $L_{Amax}$ and $L_{night}$ (night-time noise indicator as defined by the END – see paragraph 1.3.4 below). Appendix 2 describes this in detail. For now let it suffice to say that a choice for an $L_{night}$ level ties the $L_{Amax}$ related effects to a maximum and therefore allows for a protective/conservative approach.

**Fig. 1.6**
**Relation between $L_{night}$, $L_{Amax}$ and SEL**




*Source: European Commission, 2000*

Fig. 1.6 is based on a sound recording in a bedroom for one night. The top of the peaks are the $L_{Amax}$ levels, the total energy is the $L_{night}$ (thick horizontal line). The sound energy in one event is the SEL (not represented). In reality the $L_{night}$ is the average over all nights in one year. This reasoning applies also to the issue of long-term average. A value for an arbitrary single night will, except in extreme cases, bear no relationship to an individual's long-term health status, whereas a sustained sufficiently high level over a long period may.

### 1.3.3 NUMBER OF EVENTS

There is no generally accepted way to count the number of (relevant) noise events. Proposals range from the number of measured $L_{Amax}$, the number of units (vehicles, aeroplanes, trains) passing by, to the number exceeding a certain $L_{Amax}$ level (commonly indicated by NAxx; NA70 is the number of events higher than 70 dB).

### 1.3.4 CONVERSION BETWEEN INDICATORS

#### *1.3.4.1 Introduction*

$L_{night}$ is defined as the 1 year $L_{Aeq}$ (exposure to noise) over 8 hours outside at the most exposed facade. For the purpose of strategic noise mapping and reporting the height is fixed at 4 metres. As $L_{night}$ is a relatively new definition and because the studies rarely cover such a long period, the research data are rarely expressed in $L_{night}$. The most frequently used noise descriptor in sleep research is the $L_{Amax}$ or SEL near the sleeper. This means that a considerable amount of conversion work needs to be done if relations are to be expressed in $L_{night}$. There are four issues:

- conversion between SEL and $L_{Amax}$
- conversion from instantaneous to long-term
- conversion from inside to outside
- conversion from (outside) bedroom level to most exposed façade.

Further background information on these issues is provided in section 1.3.5. This section details the conversions that are actually carried out.

### *1.3.4.2 SEL to $L_{Amax}$*

SEL is only used for aircraft noise in this report and, according to Ollerhead et al. (1992) from ground-based measurements, the following relation was found:

$$SEL = 23.9+0.81*L_{Amax} \quad [1].$$

A more general approach can be used to estimate SEL for transportation noise.

If the shape of the time pattern of the sound level can be approximated by a block form, then $SEL \approx L_{Amax} + 10\lg t$, where t (in seconds) is the duration of the noise event. This rule can be used, inter alia, for a long freight train that passes at a short distance. When t is in the range from 3 to 30 seconds, then SEL is 5–15 dB higher than $L_{Amax}$. For most passages of aircraft, road vehicles or trains, the shape of the time pattern of the sound level can be better approximated with a triangle. If the sound level increases with rate a (in dB per second), and thereafter is at its maximum for a short duration before it decreases with rate -a, then $SEL \approx L_{Amax} - 10\lg(a) + 9.4$. Depending on the distance to the source, for most dwellings near transportation sources the rate of increase is in the order of a few dB per second up to 5 dB per second. When (a) is in the range from 9 dB to 1 dB per second, then SEL is 0–9 dB higher than $L_{Amax}$.

### *1.3.4.3 Events to long-term*

When the SEL values are known (if necessary after converting from $L_{Amax}$) they can be converted to $L_{night}$. In general terms, the relation between $L_{night}$ and SEL is:
$L_{night} = 10*\lg \sum_i 10^{SEL_i/10} - 10*\lg(T)$.

If all (N) events have approximately the same SEL level, this may be reduced to:

$$L_{night} = SEL + 10*\lg(N) - 70.2 \quad [2],$$

in which:
N = the number of events occurring in period T;
T = time during which the events occur in seconds. For a (night) year $10\lg(T)$ is 70.2.

The notation adheres to the END where the $L_{night}$ is defined as a year average at the most exposed facade. Any reference to an inside level is noted as such, that is, as $L_{night,inside}$. In order to avoid any doubt the notation $L_{night,outside}$ may be used, for instance in tables where both occur.

### *1.3.4.4 Inside to outside*

As the $L_{night}$ is a year value, the insulation value is also to be expressed as such. This means that if the insulation value is 30 dB with windows closed and 15 dB with windows open, the resulting value is 18 dB if the window is open 50% of the time. If these windows are closed only 10% of the time, the result is little more than 15 dB. The issue is complicated by the fact that closing behaviour is, to a certain extent, dependent on noise level. When results about effects are expressed with indoor (that is, inside bedrooms) exposure levels, they need to be converted to $L_{night}$, in accordance with the END definition. The most important assumption is the correction for inside levels to outside levels. An average level difference of 21 dB has been chosen, as this takes into account that even in well-insulated houses windows may be open a large part of the year. In general:

$$L_{night} = L_{night,inside} + Y \text{ dB} \qquad [3].$$

Y is the year average insulation value of the (bedroom) facade. In this report a default value of 21 dB is used (see also section 1.3.5). It should be stressed that this conversion is thought to be highly dependent on local building habits, climate and window opening behaviour.

*1.3.4.5 Most exposed facade*

If an inside level is converted to an outside level with [3], it is assumed that this is equivalent to an $L_{night}$ value on the most exposed facade. No information is available on bedroom position and use, so no explicit conversion factor can be given in this report.

This means that the effect estimated on the basis of $L_{night}$ corresponds to an upper limit, because part of the bedrooms will be on a less exposed facade. If an estimate of the exposed population is based on a relation derived with [3], the actual prevalence will be less. From a practical point of view the most exposed facade safeguards protection in cases where there is a possibility that rooms can be swapped.

It should be pointed out that the above does not apply if a relation is based on $L_{night}$ values which are directly measured or computed. These relations will show a large variation because of a misclassification effect, but they give a "correct" estimate of the prevalence of effects in the population. In other words, in some cases a low effect may be attributed to a high $L_{night}$ because the bedroom is on the quiet side.

### 1.3.5 INSIDE/OUTSIDE DIFFERENCES

Night-time environmental noise affects residents mainly inside their homes. In order to protect residents inside their homes from noise from outside sources, attention should be focused on windows since they are generally the weakest points in the sound propagation path. Roofs must also be considered with regard to aircraft noise.

There are many types of window in the EU, varying from single thin panes within frames without additional insulation, to four-pane windows within insulated frames. The simplest types of facade have a sound reduction (from outside to inside) of usually less than 24 dB, and the most elaborate facades (built to cope with cold climates, for example), have sound reductions of more than 45 dB. In central Europe, most windows are double-glazed, mounted in a rigid and well-insulated frame. Their range of sound reduction is between 30 dB and 35 dB when closed.

When night-time environmental noise reaches high levels, residents tend to close their bedroom windows (cf. Langdon and Buller, 1977; Scharnberg et al., 1982; Schreckenberg et al., 1999; Diaz et al., 2001). The studies by Scharnberg et al. and Schreckenberg et al. found that more than 50% of bedroom windows are closed when outside road traffic noise levels exceed 55 dB ($L_{Aeq}$). These findings have been replicated in Sweden, according to recent results from the Swedish soundscape research programme on road traffic noise (Fig. 1.7). Nevertheless, while residents with closed windows reported a reduction of sleep disturbances due to noise, they also reported an increase in sleep disturbances due to poor ventilation. Schreckenberg et al. (1999) report a much steeper increase in the incidence of closed windows when road traffic noise reaches high levels than is the case with increased levels of railway noise. Even when night-time noise levels reach 55 B, only 35% of the residents exposed to railway noise reported that they closed their windows at night.

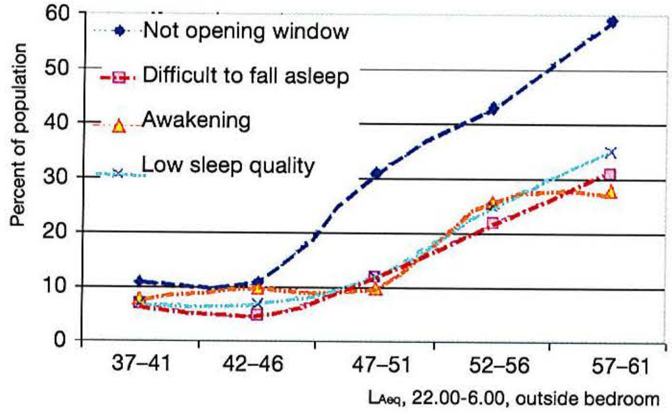



**Fig. 1.7**
**Results from Swedish soundscape research programme on road traffic noise**

*Source: Öhrström, in European Commission, 2002a.*

When windows are slightly open, outside sound levels are usually reduced by 10–15 dB. It should be kept in mind that most European residents want to keep their bedroom windows slightly open at night in order to provide proper ventilation (Scharnberg et al., 1982; Lambert and Plouhinec, 1985; Lambert and Vallet, 1994), and the WHO paper on community noise (WHO, 1999) also recommends that people should be able to sleep with their bedroom windows open.

Passchier-Vermeer et al. (2002) carried out detailed noise measurements inside and outside the bedroom and at the same time measured window position with sensors. The results (Table 1.3) showed that windows are fully closed only in 25% of the nights.

| Window position | % nights |
|---|---|
| Closed | 25 |
| Slightly open | 43 |
| Hand width | 23 |
| Half open | 5 |
| Fully open | 4 |

**Table 1.3**
**Window positions during research period (April-November)**

This results in average inside/outside differences of around 21 dB, with there being only a slight difference between single- and double-glazed windows (Table 1.4). The survey did not include dwellings which had been specifically insulated against noise. Nevertheless, there was a large variation in insulation values.

| | Single-glazed window | Double-glazed window |
|---|---|---|
| Average difference at night | 21.3 | 22.2 |

**Table 1.4**
**Average inside/outside differences in dB**

It should be stressed that this figure only applies to facades that have not been fitted with special appliances to reduce noise impact. To give an extreme example of where this general finding does not apply, rooms may be equipped with air conditioning so that windows can stay closed or could even be sealed. Less drastic provisions are sound-attenuated ventilation openings. Little is known, however, about the inhabitants' experiences (long-term use, appreciation) of these and other solutions. For example, sound-attenuated ventilation openings are sometimes blocked in order to cut out draughts.

### 1.3.6 BACKGROUND LEVEL

A simple definition of background level or "ambient noise" level is the noise that is not targeted for measurement or calculation. Background noise can interfere with the target noise in a number of ways. It can:

- mask the signal
- interact physically
- interact psychologically.

As this report is often dealing with low-level target noise, masking is an important issue. The other two interactions are more important in the domain of annoyance.
Masking, however, is a complex process. The human auditory system is uncannily good at separating signals from "background". Microphones (and the software behind them) have been slow to catch up, as the unsatisfactory results show when it comes to automatically recognizing aircraft in long-term unmanned measuring stations.

The rule of thumb that a noise can be considered masked if the signal is 10 dB below the background is only valid if the noises have the same frequency composition and if they actually occur at the same time. This is particularly important to stress where $L_{Aeq}$ levels are compared: even a relatively continuous motorway of 50 dB cannot mask aircraft noise of 30 dB, because this may be composed of five aircraft arriving at an $L_{Amax}$ of 57 dB. Neither can birdsong, because the frequency domains do not overlap.

Another factor relevant for this report is that background levels are lower at night-time than they are in the daytime. This is true for most man-made noises, but also for the natural background levels as wind speeds at night slow down.

Most levels mentioned in this report do not take background levels into account – explicitly. Where long-term $L_{Aeq}$ levels are related to effects like hypertension and self-reported sleep disturbance, background levels are ignored, but they could obscure the effect at the lower end of the scale. This then influences the lowest level where an effect starts to occur.

In sleep laboratory studies the background level is kept as low as possible, around 30 dB. The background of the instrumentation is 20 dB.

In semi-field experiments it has been found that background noise levels inside bedrooms are very low, partly because people tend to choose their bedrooms on the quiet side of the building. This may have the side-effect of exposing children to higher levels.

### 1.3.7 CHOICE OF INDICATORS FOR REGULATORY PURPOSES

From the scientific point of view the correct choice for a noise indicator is its performance in predicting the effect. There are, however, a number of additional criteria which may influence the choice. Firstly, for different health end points different indicators could be suitable. Further considerations are of a more political nature, as mentioned in the *Position Paper* on EU noise indicators (European Commission, 2000). Indicators should also be easy to explain to the public – intuitively understandable, avoiding unnecessary breaks with current practice and enforceable. This is probably why in many countries $L_{Amax}$ is a popular indicator: it has undeniable qualities in these areas.

This is also the case for $L_{Aeq}$ indicators for short periods of, for example, one or a few hours in the middle of the night. Other fashionable indicators are those looking at numbers above a threshold.

For these indicators the relation between health end points and their values is either not well established, or the correlation between them and current indicators is high, or the correlation between the indicator and an effect is low.

## 1.4 EXPOSURE IN THE POPULATION

### 1.4.1 NOISE LEVELS

Surprisingly little information is available on the exposure of houses to night-time noise. It is possible that, in a few years time, the END will lead to the creation of a substantial database on these levels, but up till now only two countries have detailed data available (Table 1.5).

**Table 1.5 Percentage of dwellings per noise class of $L_{night}$ in dB**

| | $L_{night}$ in dB | | | | |
|---|---|---|---|---|---|
| Country | 40–45 | 46–50 | 51–55 | 56–60 | 61–65+ |
| Switzerland (Müller-Wenk, 2002) | – | 24% | 14% | 7% | 2% |
| Netherlands (Nijland and Jabben, 2004) | 25% | 31% | 19% | 6% | 1% |

Notwithstanding the obvious differences between these two countries, the data show a remarkable similarity.

A first result of the END (see Table 1.6) comes from a study into night regulations for (large) airports (Wubben and Busink, 2004).

**Table 1.6 Number of inhabitants within 45 $L_{night}$ contour**

| Airport | Number of inhabitants | Number of night operations per year | Night operations as percentage of daytime operations |
|---|---|---|---|
| Amsterdam | 21 863 | 23 462 | 5.8% |
| Frankfurt | 134 651 | 46 662 | 10.1% |
| London | 477 289 | 26 465 | 5.7% |
| Paris | 180 184 | 51 683 | 10.3% |

### 1.4.2 REPORTED NIGHT-TIME NOISE DISTURBANCE

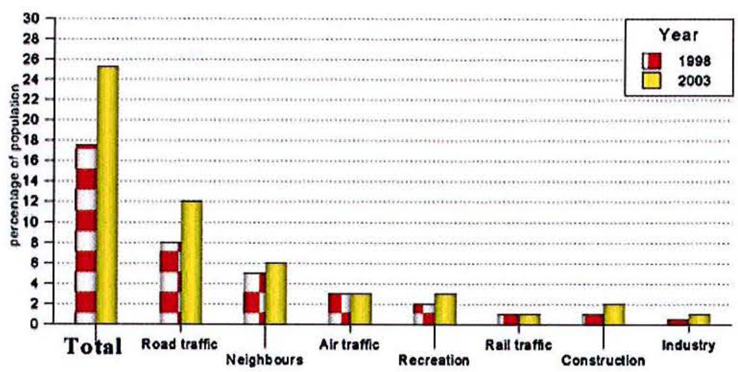
Complaints about night-time exposure to noise are widespread and not exactly new: Roman writers used to complain about the racket in the streets at night (Juvenal, 160). Surprisingly, little detailed information is available today.

Nevertheless, data collected from a few Member States can help to give an impression of the order of magnitude of effects.

Fig. 1.8 shows the relative contributions to overall sleep disturbance caused by noise from different sources in the Netherlands. These data were derived from surveys in 1998 and 2003 (van Dongen et al., 2004) in which 4000 and 2000 people, randomly selected, were asked: "To what extent is your sleep disturbed by noise from [source mentioned]..." on a scale from 1 to 10. People recording the three highest points in the scale were considered "highly disturbed", according to an international convention. The totals are calculated from the number of people reporting serious sleep disturbance from one or more sources.

Unfortunately, comparable research data from other countries or regions is not available, and there is reason to believe that there may be considerable differences in the figures. Since this study is based on a survey conducted in the Netherlands, it is not representative for other Member States in the EU. General (not specific for night-time) annoyance data from Germany and the United Kingdom give an indication that similar numbers of people are affected.

**Fig. 1.8 Percentage of population highly disturbed by noise during sleep in the Netherlands**




However, the fact that other noise nuisances may contribute significantly to overall sleep disturbance should not be overlooked. Further research on this topic is needed in order to gain an insight into the contribution of various noise sources to sleep disturbance.

## 1.5 CONCLUSIONS

The methods and criteria for deriving guidelines rest on well-established procedures from epidemiology. To relate the effects to the dose, standard metrics will be used wherever available. If possible, the values found in literature will be converted to avoid confusion. Most of the conversions are relatively straightforward and depend on physical laws; others, in particular the conversion between outside and inside levels, depend on local factors and should be used only if no other information is available.

Information about night-time noise exposure is relatively scarce, despite 10 EU Member States having limit values for night-time noise. The END could substantially increase this information (large-scale noise mapping is foreseen in 2007), increasing the demand for guidance.

# CHAPTER 2

# THE RELATION BETWEEN SLEEP AND HEALTH

*A night of quiet and repose in the profound silence of Dingley Dell, and an hour's breathing of its fresh and fragrant air on the ensuing morning, completely recovered Mr Pickwick from the effects of his late fatigue of body and anxiety of mind.*

*(Charles Dickens, The Pickwick Papers, 1836)*

## 2.1 SLEEP, NORMAL SLEEP, DEFINITIONS OF SLEEP DISTURBANCE, CHARACTERISTICS MECHANISMS, THE INSOMNIA MODEL

### 2.1.1 NORMAL SLEEP (OBJECTIVE MEASUREMENTS)

Sleep is part of living and, along with being awake, forms an inherent biological rhythm (Cooper, 1994). Normal sleep can be defined in an objective or subjective manner. The objective criteria are defined using a polysomnographic recording (PSG) of sleep, the method that measures different physiological functions during sleep. Minimal polygraphic requirements to measure sleep adequately include two channels of electroencephalography (EEG), one channel for the electrooculogram (EOG), and one channel for the submental electromyography (EMG). In routine PSG, additional channels are used to assess respiration, leg movements, oxygenation and cardiac rhythm (Ebersole and Pedley, 2003).

Scoring of sleep stages is usually done on an epoch-by-epoch basis, with a 30-second length used as a standard. Epochs are scored according to the guidelines of Rechtschaffen and Kales (1968). Each epoch is scored as the stage that occupies more than 50% of that epoch. Sleep can be divided into the following stages.

- **Arousal** is not a uniform concept and has been defined differently by different researchers. Commonly, the occurrence of alpha rhythms is required for EEG arousal. Depending on the additional requirements and on the length of time that the slower cortical rhythms are interrupted, arousals have been called, for instance, micro-arousal, minor arousal, EEG awakening or transient activation phases. The American Sleep Disorders Association (1992, 1997) devised a scoring system, taking sequences of 3–15 seconds into account for transient arousals which are not transferred to macroscopic behavioural awakening. Eleven further criteria must be met (see also Chapter 3, section 3.1.2).

- **Vegetative arousals** are activations of the sympathic nervous system.

- **Stage W** corresponds to the waking stage and is characterized by alpha activity or low-voltage, mixed-frequency EEG activity. Rapid eye movements (REMs), eye blinks, and tonic EMG activity are usually present.

- **Stage 1** is scored when more than 50% of an epoch is low-voltage, 2–7 Hertz (Hz) activity. Vertex waves may occur in late stage 1. Slow rolling eye movements lasting several seconds are routinely seen early in stage 1, but K complexes and sleep spindles are absent by definition. Tonic EMG activity is usually less than that of relaxed wakefulness.

- **Stage 2** requires the presence of sleep spindles or K complexes, and less than 20% of the epoch contains delta activity. Bursts of sleep spindles must last at least 0.5 seconds before they can be scored. K complexes are defined as biphasic vertex sharp waves with a total duration of greater than 0.5 seconds.

- **Stage 3** is scored when 20–50% of an epoch consists of delta activity that is 2 Hz or slower and is greater than 75 µV in amplitude. Sleep spindles may or may not be present.

- **Stage 4** is scored when more than 50% of an epoch consists of delta activity that is 2 Hz or slower and is more than 75 µV in amplitude. Reliable differentiation of stage 3 and stage 4 sleep is difficult by visual inspection, and most laboratories combine stages 3 and 4 into a single determination of slow-wave sleep (SWS).

- **Stage REM** is characterized by relatively low-voltage, mixed-frequency EEG activity with episodic REMs and absent or markedly reduced axial EMG activity. Phasic EMG activity may occur, but tonic activity must be at a level that is as low as, or lower than, that during any other time in the study. Sleep spindles and K complexes are absent. Series of 2- to 5- Hz vertex-negative "saw-tooth waves" occur, particularly just before phasic REM activity. The requirements to score sleep as REM sleep are: REMs, low or absent axial EMG, and typical mixed-frequency EEG recording that does not preclude the scoring of REM.

Movement time is scored when more than 50% of an epoch is obscured by movement artefact. Movement time must be preceded or followed by sleep and is thus distinguished from movement occurring during wakefulness.

Additional sleep values are determined from each sleep study and contribute to the clinical interpretation of the study. These additional variables include the following.

- **Recording time** is the time elapsed between "lights out" and "lights on" at the end of the study.

- **Total sleep time (TST)** is the total time occupied by stage 1, stage 2, SWS and REM sleep.

- **Sleep efficiency (SE)** is defined as total sleep time divided by recording time and is expressed as a percentage.

- **Sleep latency (SL)** is the time from "lights off" to the first epoch scored as sleep. Some authors prefer to use the first epoch of stage 2 in order to be more confident about identifying the onset of sustained sleep. However, when sleep is very disrupted, there may be an extended interval from recognition of stage 1 until an epoch that can be scored as stage 2.

- **REM latency** is the time from sleep onset (as described earlier) to the first time period scored as REM, minus any intervening epochs as wakefulness.

- **Sleep stage percentages** (% in stage 1, stage 2, SWS and REM sleep) are determined by dividing time recorded in each sleep stage by total sleep time.

- **Wake after sleep onset (WASO)** is time spent awake after sleep onset.

The objective criteria defining normal sleep are based on: sleep latency, total sleep time, sleep efficiency and the number of awakenings, including cortical arousals. However, all these parameters are age-related, sometimes also gender-related, and may vary from one individual to another.

Normal sleep has a clearly defined architecture that is relatively stable. Predictable changes in sleep architecture occur with age. Beginning in middle age, SWS becomes less prominent, the number of awakenings increase, and sleep efficiency decreases. Published information on normal sleep can serve as an outline for normal values in PSG (Williams, Karacan and Hursch, 1974; see also Table 2.1), but each laboratory must study control subjects to identify any significant effects on sleep that result from differences in technique or environment (Ebersole and Pedley, 2003).

**Table 2.1**
**Average normal values for adults of different ages**

| Sleep parameter (normal values) | 20–29 years | 40–49 years | 60–69 years |
|---|---|---|---|
| TST (min) | 419 | 389 | 407 |
| Sleep efficiency (TST/TIB[a]) | 95% | 91% | 90% |
| WASO | 1% | 6% | 8% |
| Stage 1 (% of TST) | 4% | 8% | 10% |
| Stage 2 (% of TST) | 46% | 55% | 57% |
| SWS (% of TST) | 21% | 8% | 2% |
| REM (% of TST) | 28% | 23% | 23% |
| Sleep latency (min) | 15 | 10 | 8 |

[a] *Time in bed*
*Source: Williams, Karacan and Hursch, 1974.*

Passchier-Vermeer (2003a) reports that subjects not exposed to loud night noise typically report waking up one and a half to two times during an average sleep period, while the number of EEG awakenings including cortical arousals averages 10–12 per night (Table 2.2).

**Table 2.2**
**Parameters of normal sleep**

| Subjects not exposed to loud night noise | Subjective report of number of awakenings | Number of EEG awakenings |
|---|---|---|
| Normal adult subjects | 1.5–2 | 10–12 |

*Source: Passchier-Vermeer, 2003a.*

Night arousals result in fragmented sleep, which in turn leads to excessive daytime sleepiness (EDS). The gold standard for the assessment of EDS is the multiple sleep latency test (MSLT) (see Table 2.3), which provides an objective quantification of "sleepiness". The preceding night's sleep requires the PSG to ensure adequate sleep and to exclude sleep disruption. During the day, four or five nap times are scheduled every two hours. For each scheduled nap time the patient lies down and assumes a comfortable sleep position with the technician's instructions to "close your eyes and attempt to sleep". Each nap is terminated 20 minutes after the nap time started if no sleep occurred; or after 15 minutes of continuous sleep as long as sleep onset (SO) criteria are met before the end of 20 minutes; or after 20 minutes if the patient awakens, even if the patient has been asleep less than 15 minutes. The patient is instructed to stay awake between the nap periods.

Table 2.3
Mean sleep latency

| Group | MSLT (min) | No REM SO (% of group) | 1 REM SO (% of group) | 2 or more REM SO (% of group) |
|---|---|---|---|---|
| Narcoleptics | 2.9 ± 2.7 | 2 | 2 | 96 |
| EDS (non-narcoleptic, non-sleep apnoeic) | 8.7 ± 4.9 | 92 | 8 | 0 |
| Controls | 13.4 ± 4.3 | 100 | 0 | 0 |

*Source: Ebersole and Pedley, 2003.*

## 2.1.2 DEFINITIONS OF DISTURBED SLEEP

Sleep disorders are described and classified in the International Classification of Sleep Disorders (ICSD) (American Academy of Sleep Medicine, 2005).

When sleep is permanently disturbed and becomes a sleep disorder, it is classified in the ICSD 2005 as "environmental sleep disorder". Environmental sleep disorder (of which noise-induced sleep disturbance is an example) is a sleep disturbance due to a disturbing environmental factor that causes a complaint of either insomnia or daytime fatigue and somnolence. Secondary deficits may result, including deficits in concentration, attention and cognitive performance, reduced vigilance, daytime fatigue, malaise, depressed mood and irritability. The exact prevalence is not known. Fewer than 5% of patients seen at sleep disorder centres receive this diagnosis. The sex ratio is not known. The disorder may occur at any age, although the elderly are at more risk for developing this condition (American Academy of Sleep Medicine, 2005).

### *2.1.2.1 Insomnia*

In the ICSD 2005 the section on insomnia includes a group of sleep disorders all of which have in common the complaint of insomnia (adjustment insomnia, psychophysiological insomnia, paradoxical insomnia, idiopathic insomnia, etc.), defined as repeated difficulty with sleep initiation, duration, consolidation or quality that occurs despite adequate time and opportunity for sleep and results in some form of daytime impairment. Insomnia is a symptom that often arises from primary medical illness, mental disorders and other sleep disorders, but may also arise from abuse or exposure. However, the general criteria for insomnia are the same for all subgroups of insomnias.

### *2.1.2.2 General criteria for insomnia*

A. A complaint is made concerning difficulty initiating sleep, difficulty maintaining sleep, waking up too early or sleep that is chronically non-restorative or poor in quality. In children, the sleep difficulty is often reported by the carer and may consist of observed bedtime resistance or inability to sleep independently.

B. The above sleep difficulty occurs despite adequate opportunity and circumstances for sleep.

C. At least one of the following forms of daytime impairment related to the night-time sleep difficulty is reported by the patient:

- fatigue or malaise
- attention, concentration, or memory impairment
- social or vocational dysfunction or poor school performance
- mood disturbance or irritability

- daytime sleepiness
- motivation, energy, or initiative reduction
- proneness to errors or accidents at work or while driving
- tension, headaches, or gastrointestinal symptoms in response to sleep loss
- concerns or worries about sleep.

Defining the cause of a sleep/wake disturbance in an insomnia patient is a complex task since it is often multifactorial. In fact, a confluence of factors that support multiple insomnia diagnoses may be judged important in many patients with insomnia. Although selection of a single diagnosis is preferable and this selection may be appropriate, such a selection should not necessarily imply the absence of a subset of factors relevant to an alternate diagnosis. When criteria for multiple insomnia diagnosis are met, all relevant diagnosis should be assigned.

#### *2.1.2.3 Environmental sleep disorder*

In the ICSD 2005, environmental sleep disorder is listed in the category of "other sleep disorders". Noise-induced sleep disturbance is one of the disturbing environmental factors that cause a complaint of either insomnia or daytime fatigue and somnolence.

The diagnostic criteria for environmental sleep disorder are the following.

A. The patient complains of insomnia, daytime fatigue or a parasomnia. In cases where daytime fatigue is present, the daytime fatigue may occur as a result of the accompanying insomnia or as a result of poor quality of nocturnal sleep.

B. The complaint is temporally associated with the introduction of a physically measurable stimulus or environmental circumstance that disturbs sleep.

C. It is the physical properties, rather than the psychological meaning of the environmental factor, that accounts for the complaint.

D. The sleep disturbance is not better explained by another sleep disorder, medical or neurological disorder, mental disorder, medication use or substance use disorder.

The prevalence of environmental sleep disorder is not known. Fewer than 5% of patients seen at sleep disorder centres receive this diagnosis.

International standardization and quantification for measurement of the depth of sleep is based on Rechtschaffen and Kales criteria from 1968. Sleep is divided into 30-second epochs, and a phase is only assessed if the specific features are evident for more than 50% of the epoch length. For example, wakefulness is scored when at least 15 seconds of continuous awakening is present. Arousal reactions not leading to macroscopic awakening were not included in the definition by Rechtschaffen and Kales. With the arousals as described by the American Sleep Disorders Association (1992) it is possible to display subvigilant sleep fragmentation, caused by intrinsic sensory and autonomic alarm reactions. An arousal index providing the arousal density (events per hour of sleep) was taken as a measure of the degree of severity. In one hour, 10–20 arousals are considered as normal in healthy adults. However, the use of EEG arousals with the American Sleep Disorders Association definition provides no sufficient explanation of daytime sleepiness (Ali, Pitson and Stradling 1996; Ayas et al., 2001) unless they are accompanied by vegetative arousals.

Regarding noise, different vigilance level assessments in various functional systems are important. Dumont, Montplaisir and Infante-Rivard (1988) proposed investigations of vegetative, motor and sensory functions independently of each other. One of the possible factors indicating disturbed sleep is a vegetative arousal index. A vegetative arousal index of more than 30 per hour is certainly considered as serious, more than 20 per hour as intermediate and more than 10 as a light form of sleep disorder.

With respect to insomnia (section 2.1.2), there is the possibility of misclassification if the general practitioner (GP) overlooks excessive noise as the possible cause of the complaint. There is also the possibility that the insomnia is aggravated by noise.

### 2.1.3 CONCLUSIONS

Published information on normal sleep can serve as an outline for normal values in PSG. However, these values are only informative, because each sleep laboratory must study control subjects to identify any significant effects on sleep that result from differences in technique or environment. Excessive daytime sleepiness is a consequence of disturbed night sleep and can be objectively assessed by MSLT, which provides an objective quantification of "sleepiness".

## 2.2 LONG-TERM HEALTH RISK MEDIATED BY SLEEP DISTURBANCES

### 2.2.1 STRESSORS, NEUROBEHAVIOURAL DATA AND FUNCTIONAL NEUROIMAGING

It is generally accepted that insufficient sleep and particularly sleep loss has a great influence on metabolic and endocrine functions (Spiegel, Leproult and van Cauter, 1999), as well as on inflammatory markers, and contributes to cardiovascular risk. C-reactive protein (CRP) as a major marker of the acute phase response to inflammatory reaction promotes secretion of inflammatory mediators by vascular endothelium and may be therefore directly involved in the development of atherosclerotic lesions. CRP as a risk predictor of strokes and heart attacks linearly increases with total and/or partial sleep loss (Meier-Ewert et al., 2004).

An additional factor, closely linked to cardiovascular health, glucose regulation and weight control, is leptin. Leptin is one of the major regulators of energy homeostasis and its circadian profile interacts closely with sleep.

Secretion of leptin increases at night and decreases during the day. A decreased leptin level, that is connected with sleep loss, increases appetite and predisposes to weight gain, impaired glucose tolerance and impaired host response.

Other studies have focused on how sleep loss affects neurobehavioural functions, especially neurocognitive performance. Functional brain imaging and EEG brain mapping studies show that the patterns of functional connectivity between brain regions, evident in the performance of specific cognitive tasks, are altered by sleep loss (NCSDR, 2003). According to this finding, the maintenance of sustained performance during sleep loss may depend upon regional functional plasticity.

Cumulative waking, neurocognitive deficits and instability of state that develop from chronic sleep loss have a basis in a neurobiological process that can integrate homoeostatic pressure for sleep across days. Increased efforts have helped to determine the roles of REM and non-REM sleep in memory.

Functional brain imaging techniques, such as positron emission tomography (PET), functional magnetic resonance imaging (fMRI), magnetic resonance spectroscopy (MRS), single photon emission computed tomography (SPECT) and magneto-electroencephalography (MEG), have recently been analysed in a study of sleep and waking (NCSDR, 2003). These techniques allow the measurement of metabolic and neurochemical activity throughout the brain, and can reveal dynamic patterns of regional cerebral activity during various brain states, including stages of sleep and levels of alertness during wakefulness or during functional challenge. These techniques can also help identify both normal and abnormal sleep/wake processes.

In the last five years, functional neuroimaging techniques (particularly PET) have revealed that non-REM sleep is associated with the deactivation of central encephalic regions (brainstem, thalamus, basal ganglia) and multimodal association cortices (for instance, prefrontal and superior temporal/inferior parietal regions). REM sleep is characterized by reactivation of all central encephalic regions deactivated during non-REM sleep except the multimodal association areas. PET studies during sleep-deprived wakefulness have revealed regional cerebral deactivations that are especially prominent in prefrontal and inferior parietal/superior temporal cortices, and in the thalamus. This pattern is consistent and helpful in explaining the nature of cognitive performance deficits that occur during sleep loss. As revealed by means of fMRI techniques during cognitive task performance, the maintenance of performance following sleep loss may be a function of the extent to which other cortical brain regions can be recruited for task performance in the sleep-deprived state.

PET, SPECT and fMRI studies have revealed, in depressed patients, initially elevated activation in anterior cingulate and medial orbital cortices (NCSDR, 2003). In these patients, sleep deprivation reduces this regional hyperactivation, and improvements in mood are a function of the extent to which this activity is reduced. These studies point to possible mechanisms by which antidepressant drugs may exert their effects. Further research should be oriented towards neuroimaging and measurements of changes in the brain's metabolic activity at the neurotransmitter level.

### 2.2.2 SIGNALS MEDIATED BY A SUBCORTICAL AREA (THE AMYGDALA), THE ROLE OF STRESS HORMONES IN SLEEP DISTURBANCE AND THEIR HEALTH CONSEQUENCES

Experimental as well as clinical studies (Waye et al., 2003; Ising and Kruppa, 2004) showed that the first and fastest signal of stressors introduced by noise is detected and mediated by a subcortical area represented by the amygdala while the stress response to noise is mediated primarily by the hypothalamus-pituitary-adrenal (HPA) axis. A major intrinsic marker of the circadian rhythm is in the level of circulating corticosteroids derived from activity within the HPA axis. A protracted stress response with activation of the HPA axis is a major physiological response to environmental stressors. The cortisol response to awakening is an index of adrenocortical activity, and long-term nocturnal noise exposures may lead, in persons liable to be stressed by noise, to permanently increased cortisol concentration above the normal range. The hypothesis that an increased risk of cardiovascular diseases is connected with stress concepts is generally accepted (Ekstedt, Åkerstedt and Soderstrom, 2004; Ising and Kruppa, 2004). Stress reactions may lead to derangement of normal neurovegetative and hormonal processes and influence vital body functions. Cardiovascular parameters such as BP, cardiac function, serum cholesterol, triglycerides, free fatty acids and haemostatic factors (fibrinogen) impede the blood flow through increased viscosity and presumably blood sugar concentration as well. Insulin resistance and diabetes mellitus, stress ulcers and immune system deficiency are also frequent consequences of stress reaction. Disturbed sleep may lead to immunosuppression and diminished protein synthesis (Horne, 1988).

As well as nonspecific effects of the stress response on the functioning of the immune system, there is considerable evidence for a relation between sleep, especially SWS, and the immune system (Brown, 1992). This evidence includes surges of certain immune parameters and growth hormones at onset of SWS, correlation of non-REM sleep, total sleep time and sleep efficiency with natural killer cell activity, and correlation of SWS with recovery from infections. These data, taken together with information on the effect of intermittent transportation noise on SWS during the first sleep cycles and overnight, suggest that the immune response could also be impacted directly by environmental noise during sleep (Carter, 1996).

### 2.2.3 SLEEP RESTRICTION, ENVIRONMENTAL STRESSORS (NOISE) AND BEHAVIOURAL, MEDICAL AND SOCIAL HEALTH CONSEQUENCES OF INSUFFICIENT SLEEP: RISK OF MORBIDITY AND MORTALITY

Sleep restriction due to environmental stressors leads to primary sleep disorders, but health is also influenced by the consequence of stress response to noise mediated by the HPA axis and/or by restriction of specific sleep stages (see above).

Sleep restriction leads, in approximately 40% of affected subjects, to daytime sleepiness that interferes with work and social functioning. Excessive daytime sleepiness is thus a major public health problem, as it interferes with daily activities, with consequences including cognitive problems, motor vehicle accidents (especially at night), poor job performance and reduced productivity (Lavie, Pillar and Malhotra, 2002). In the last decade, experimentally based data have been collected on chronic restriction of sleep (by 1–4 hours a night), accumulating daytime sleepiness and cognitive impairment. Most individuals develop cognitive deficits from chronic sleep debt after only a few nights of reduced sleep quality or quantity. New evidence suggests additional important health-related consequences of sleep debt related to common viral illnesses, diabetes, obesity, heart disease, depression and other age-related chronic disorders.

The effects and consequences of sleep deprivation are summarized in Table 2.4 (Lavie, Pillar and Malhotra, 2002).

The relationship between sleep quantity and quality and estimates of morbidity and mortality remains controversial. Epidemiological data (NCSDR, 2003) suggest that habitually short sleep (less than 6 hours sleep per night) is associated with increased mortality. Epidemiological studies in recent years elucidated, however, that too much sleep is a problem as well. Kripke et al. (2002) evaluated a questionnaire study of 1.1 million men and women aged 30–102 years and found the lowest mortality risk between respondents sleeping 7 hours per night.

| Type | Short-term | Long-term |
| --- | --- | --- |
| Behavioural | Sleepiness<br>Mood changes<br>Irritability and nervousness | Depression/mania<br>Violence |
| Cognitive | Impairment of function | Difficulty in learning new skills<br>Short-term memory problems<br>Difficulty with complex tasks<br>Slow reaction time |
| Neurological | Mild and quickly reversible effects | Cerebellar ataxia, nystagmus, tremor, ptosis, slurred speech, increased reflexes, increased sensitivity to pain |
| Biochemical | Increased metabolic rate<br>Increased thyroid activity<br>Insulin resistance | Decreased weight despite increased caloric intake (in animals)<br>Diabetes, obesity (in humans) |
| Others | Hypothermia<br>Immune function impairment | Susceptibility to viral illness |

**Table 2.4**
**Consequences of sleep deprivation**

Mortality risk significantly increased when sleep duration was less than 6 or higher than 8 hours per night. Other authors have also published similar results (Patel et al., 2004; Tamakoshi and Ohno, 2004). Patel et al. (2004) in a prospective study of sleep duration and mortality risk in 5409 women confirmed previous findings that mortality risk is lowest among those sleeping 6–7 hours per night. The mortality risk for death from other causes significantly increased in women sleeping less than 5 and more than 9 hours per night. It is not clear how the length of sleep can increase this risk, although animal evidence points to a direct link between sleep time and lifespan (see section 2.5 in this chapter). Up to now, no epidemiological prospective study has been published that examines the relationship between sleep and health outcomes (morbidity and mortality) with subjective and objective estimates. Recent studies, however, show that sleep duration of least 8 hours is necessary for optimal performance and for prevention of daytime sleepiness and accumulation of sleep debt.

Environmental stressors, including noise, mostly cause insomnia. Insomnia also involves daytime consequences, such as tiredness, lack of energy, difficulty concentrating and irritability. A reasonable prevalence estimate for chronic insomnia in the general population is about 10%; for insomnia of any duration or severity this rises to between 30% and 50%, and incidence increases with ageing. In the course of perimenopausal time, women are particularly vulnerable to developing this complaint. The major consequences and co-morbidity of chronic insomnia (see Table 2.5) consist of behavioural, psychiatric and medical problems. Several studies also report a higher mortality risk (Zorick and Walsh, 2000).

**Table 2.5 Consequences of chronic insomnia**

| Type | Consequence |
|---|---|
| Behavioural | Poor performance at work, fatigue, memory difficulties, concentration problems, motor vehicle accidents |
| Psychiatric | Depression, anxiety conditions, alcohol and other substance abuse |
| Medical | Cardiovascular, respiratory, renal, gastrointestinal, musculoskeletal disorders<br>Obesity<br>Impaired immune system function |
| Mortality | Increased risk is reported |

*2.2.3.1 Behavioural consequences*

Transient (short-term) insomnia is usually accompanied by spells of daytime sleepiness and performance impairment the next day. Persistent (long-term) insomnia tends to be associated with poor performance at work, fatigue, memory difficulties, concentration problems and twice as many fatigue-related motor vehicle accidents as in good sleepers.

*2.2.3.2 Psychiatric conditions*

Epidemiological research indicates that the prevalence of any psychiatric disorder is two or three times higher in insomniacs. The risk of depression as a co-morbid state appears to be particularly strong, being approximately four times more likely in insomnia patients. Furthermore, insomnia may be an early marker for psychiatric disorders such as depression, anxiety conditions and alcohol abuse. Anxiety has been quite commonly found in insomniacs compared with the general population. About 25–40% of insomnia patients are estimated to have significant anxiety, and the abuse of alcohol and other substances is increased in insomniacs relative to good sleepers (Ford and Kamerow, 1989). Samples of unselected psychiatric patients have about a threefold increase in the frequency of insomnia compared with healthy control subjects, and the severity of the condition correlates with the intensity of the psychiatric symptoms. Among samples of outpatients who consulted their GPs for insomnia, about 50% presented with psychiatric conditions, and about half of these patients were probably depressed (Zorick and Walsh, 2000).

*2.2.3.3 Medical consequences*

Insomnia has been statistically associated with various medical conditions, including disorders of the cardiovascular, respiratory, gastrointestinal, renal and musculoskeletal systems. A large series of insomniac patients showed that poor sleepers are more than twice as much at risk of ischaemic heart disease (IHD) as good sleepers (Hyyppa and Kronholm, 1989). Insomnia patients were also shown (Irwin, Fortner and Clark, 1995) to have impaired immune system function. Keith et al. (2006) hypothesize a connection between sleep deficit as one of the possible factors to explain the rise in obesity. Hormone changes and animal experiments apparently support this.

*2.2.3.4 Mortality risk*

Only a few epidemiological studies deal with mortality in insomniacs. According to Kripke et al. (1979), reduced sleep time is a greater mortality risk than smoking, hypertension and cardiac disease. Higher death rates are also reported among short sleepers. In this respect, however, further systematic investigation of the link between insomnia, short sleep and death is desirable.

# 2.3 RISK GROUPS

Risk groups are people who may be either sensitive (showing more reaction to a stimulus than the average), are more exposed (also called vulnerable) or both.

## 2.3.1 HEALTH EFFECTS OF DISTURBED SLEEP IN CHILDREN

Although children appear to tolerate a single night of restricted sleep with no detrimental effect on performance of brief tasks, perhaps more prolonged restriction and prolonged tasks similar to those required in school would show negative effects. In addition, as children seem to require more time to recuperate fully from nocturnal sleep restriction than adults (Carskadon, Harvey and Dement, 1981a), with additional nights of partial sleep deprivation, cumulative sleepiness might become a significant problem.

Empirical data that directly address the effects of repeated sleep loss on children's mood or cognitive function are sparse. A range of clinical and observational data support a general picture that inadequate sleep results in tiredness, difficulties in focusing attention, low thresholds for negative reactions (irritability and easy frustration), as well as difficulty in controlling impulses and emotions. In some cases, these symptoms resemble attention-deficit hyperactivity disorder (ADHD).

Environmental noise experienced at home during night-time is a sometimes unpredictable and most often discontinuous event (for example traffic noise, aircraft or train noise, a noisy environment for other reasons, for instance proximity with a discotheque, etc.), that might lead to sleep disruption without leading to behavioural awakenings through the alteration of sleep microstructure, in a similar manner as other sleep disturbing events such as respiratory disturbances.

Therefore, in respect of clinical settings, we can assume that, in children, an experimental model for the consequences of noise can be represented by respiratory disturbances during sleep, such as snoring, upper airway resistance syndrome (UARS) or obstructive sleep apnoea syndrome (OSAS), either for the noise produced by snoring or for the effects on the arousal system and sleep microstructure.

For this reason, this section describes the well-studied effects of sleep breathing disorders on children's health and then evaluates the indicators of sleep disruption from the point of view of sleep microstructure.

In the literature few data on the medium- and long-term effects of disturbed sleep in children are available from the longitudinal point of view. Most reports focused on respiratory disturbances during sleep as a theoretical model to evaluate the long-term effects of disturbed sleep in children. This review reports on the medium- and long-term negative consequences of disturbed sleep on cognitive functioning, behaviour, mental health, growth and the cardiovascular system.

#### *2.3.1.1 Sleep deprivation in children*

The effects of sleep deprivation were evaluated in children. The findings only indirectly pertain to this general report, although repeated noise-induced sleep disruption favours sleep deprivation.

In another study, 15 healthy infants aged 78+/-7 days were studied during two nights: one night was preceded by sleep deprivation (kept awake for as long as possible beyond their habitual bedtime: median onset 150 min; range 0–210 min) (Thomas et al., 1996). Of the 15 children, 13 slept supine, 12 were breastfed and 4 were from smoking parents. Following sleep deprivation, infants maintained a greater proportion of quiet sleep (44% vs. 39%; p=.002). There was no measurable change in arousal propensity by either graded photic (stroboscope) or auditory stimuli (1 kHz pure tone, delivered in the midline of the cot, from 73 dB and increased in 3 dB steps to 100 dB) during quiet sleep.

Forty-nine Finnish children (26 boys/23 girls) aged 7–12 years were interviewed together with their parents and school teachers, and recorded for 72 hours with a belt-worn activity monitor during weekdays.

The objectively measured true sleep time was associated with psychiatric symptoms reported by a teacher. The decreased amount of sleep was associated more with externalizing than internalizing types of symptoms (aggressive and delinquent behaviour, attention, social, and somatic problems) (Aronen et al., 2000).

In a survey, it was also shown that out of 100 Belgian school children, aged between 9 and12 years, those with poor sleep (insomnia) were also showing more frequent poor school performance (failure to comply with expected grades) than good sleepers. The relation between poor sleep and a noisy environment was, however, not evaluated (Kahn et al., 1989).

#### 2.3.1.2 *Neurocognitive manifestations*

Several studies in adults have shown that sleep fragmentation and hypoxaemia can result in daytime tiredness and loss of concentration, retrograde amnesia, disorientation, morning confusion, aggression, irritability, anxiety attacks and depression. One could hypothesize that sleep fragmentation and hypoxaemia would affect the neuropsychological and cognitive performance also in children, where the impact of abnormal sleep may be even greater than in adults. In fact, neurocognitive and behavioural deficits and school problems have been reported recently in children with sleep-related obstructive breathing disorders (SROBD).

#### 2.3.1.3 *Attention capacity*

This represents the ability to remain focused on a task and appropriately attend to stimuli in the environment. Taken together the studies to date indicate that children with SROBD are less reflective, more impulsive, and show poorer sustained and selective attention. Blunden et al. (2000) reported that, compared to 16 controls, 16 children with mild SROBD showed reduced selective and sustained attention. Owens-Stively et al. (1997) suggested a dose–response in attention–impulsivity with moderate to severe obstructive sleep apnoea syndrome (OSAS) children showing greater deficits than mild OSAS children. Importantly, early treatment showed that attention deficits in children with OSAS are reversible (Guilleminault et al., 1982b). In another study, 12 children with moderate to severe OSAS showed a significant reduction in inattention and an improvement in aggressive and hyperactive behaviours and vigilance after surgical treatment (Ali, Pitson and Stradling, 1996).

#### 2.3.1.4 *Memory*

Rhodes et al. (1995) found inverse correlations between memory and learning performance and the apnoea hypopnea index in 14 morbidly obese children. Smaller deficits were observed by Blunden et al. (2000), who found in their sample of children with mild SROBD that mean global memory performance was in the lower end of the normal range compared to controls.

A recent study using actigraphy in normal school-age children showed that lower sleep efficiency and longer sleep latency were associated with a higher percentage of incorrect responses in working memory tasks; shorter sleep duration was associated with performing tasks at the highest load level only. Also, controlling for age, gender, and socioeconomic status, sleep efficiency and latency were significantly associated with the mean incorrect response rate in auditory working memory tasks. This study showed that sleep quality (evaluated as sleep efficiency = 100* [sleep + light sleep]/duration) is more strongly associated with performance in working memory tasks than sleep duration, suggesting that in assessing sleep, attention should be directed not only at the amount of sleep but also at sleep quality.

#### 2.3.1.5 *Intelligence*

Inspection of the mean IQ scores reported in the study by Rhodes et al. (1995) suggested that their sample of five obese children with moderate to severe OSAS performed in the borderline range whereas controls performed in the normal range. Blunden et al. (2000) showed smaller deficits in children with mild SROBD whose mean verbal and global IQ were in the lower end of the normal range.

It remains unclear as to whether the putative negative effects of SROBD on intelligence are global in nature or confined to specific areas such as verbal rather than performance or visuospatial intelligence and whether these impairments can be reversed.

#### 2.3.1.6 *Learning and school performance*

It has been widely reported (Stradling et al., 1990; Guilleminault et al., 1996; Richards and Ferdman, 2000) that children with SROBD show reduced academic performance and learning.

Weissbluth et al. (1983) found that poor academic achievers had a higher prevalence of night-time snoring (38% vs. 21%) and breathing difficulties (13% vs. 6%). Out of 297 children with SROBD (22% snorers and 18% sleep-associated gas exchange abnormalities), 40% were in the lowest 10th percentile of academic performance (Gozal, 1998) and SROBD in early childhood may continue to adversely affect learning in later years (Gozal and Pope, 2001). Gozal (1998) found in his sample of poor academic achievers that school grades improved post-adenotonsillectomy in treated but not untreated children.

As well as those with SROBD, healthy normal children with fragmented sleep (measured by actigraphy) also showed lower performance on neurobehavioural functioning (NBF) measures, particularly those associated with more complex tasks, and also had higher rates of behavioural problems (Sadeh, Gruber and Raviv, 2002). Furthermore, in normal children without sleep disorders, modest sleep restriction can also affect children's NBF. Sadeh, Gruber and Raviv (2003) monitored 77 children for 5 nights with activity monitors. On the third evening, the children were asked to extend or restrict their sleep by an hour on the following three nights. Their NBF was reassessed on the sixth day following the experimental sleep manipulation and showed that sleep restriction led to improved sleep quality and to reduced reported alertness.

These studies suggest that fragmented sleep or insufficient sleep is highly relevant during childhood and that children are sensitive to modest alterations in their natural sleep duration.

Early reports documented that untreated OSAS can have long-term negative effects, such as failure to thrive, cor pulmonale and mental retardation. These severe consequences are less common now due to early diagnosis and treatment, but recent reports have focused on other long-term effects mainly related to neurocognitive deficits, such as poor learning, behavioural problems and ADHD (Marcus, 2001).

Gozal and Pope (2001) tried to determine the potential long-term impact of early childhood snoring. Analysing questionnaires of 797 children in a low academic performance group (LP) and 791 in a high academic performance (HP) group, they found that frequent and loud snoring during early childhood was reported in 103 LP children (12.9%) compared with 40 HP children (5.1%). Therefore, children with lower academic performance in middle school are more likely to have snored during early childhood and to require surgery for snoring compared with better performing schoolmates. These findings suggest that children who experienced sleep-disordered breathing during a period traditionally associated with major brain growth and substantial acquisition of cognitive and intellectual capabilities may suffer from a partially irreversible compromise of their a priori potential for academic achievement. Three major components that result from the intermittent upper airway obstruction that occurs during sleep in children could theoretically contribute to such neurocognitive deficits, namely episodic hypoxia, repeated arousal leading to sleep fragmentation and sleep deprivation, and periodic or continuous alveolar hypoventilation.

Schooling problems may underlie more extensive behavioural disturbances such as restlessness, aggressive behaviour, EDS and poor neurocognitive test performances. Nearly 20–30% of children affected by OSAS or loud and frequent snoring show important signs of behavioural problems such as inattention and hyperactivity. Problems similar to symptoms of ADHD are linked to the presence of repeated sleep arousals, and intermittent hypoxic events, inducing a lack of behavioural inhibition with negative implications for working memory, motor control and self-regulation of motivation and affect.

In contrast with these data, Engle-Friedman et al. (2003) recently found a significant improvement of functions, at least in mild to moderate OSAS, when measured several months following an adenotonsillectomy, but they confirmed that their results could not rule out the possibility, even after treatment, of partial irreversible damage to academic function that may be detected only later in life. In addition, they stated that adults who also had deficits of neurocognitive executive functions related to the prefrontal area failed to improve significantly after treatment.

The negative long-term effects may be mediated by the irreversible alteration of the prefrontal cortex (PFC) and be related to structural changes of the brain as a consequence of both hypoxaemia and sleep fragmentation induced by OSAS or other pathologies affecting sleep.

In a recent report concerning OSAS adults, Macey et al. (2002) demonstrated grey matter loss in cerebral sites involved in motor regulation of the upper airway as well as in areas contributing to cognitive function (frontal and parietal cortex, temporal lobe, anterior cingulate, hippocampus and cerebellum). It can be argued that, in critical stages of brain development (that is, in childhood), these effects can lead to even more severe consequences, which could explain the negative long-term effects.

It is speculative to think that the remodelling of the brain could also be mediated by sleep and, therefore, sleep fragmentation could affect the process of brain plasticity (that is, the capacity of the brain to modify its structure and function over time). Recent studies showing experience-dependent gene-expression of gene *zif-268* during paradoxical sleep in rats exposed to a rich sensorimotor environment, and the role of sleep in enhancing the remodelling of ocular dominance in the developing visual cortex are also in line with the hypothesis that sleep affects neuronal plasticity and memory processes (Peigneux et al., 2001).

#### 2.3.1.7 *Neurobehavioural manifestations*

Behavioural disturbances are common in children with SRODB, with higher prevalence rates of both internalized (for instance being withdrawn, shy, anxious and psychosomatic) and externalized (for instance impulsivity, hyperactivity, aggression and delinquency) problematic behaviours (Blunden, Lushington and Kennedy, 2001). The most frequently documented problematic behaviour in children with SROBD is attention deficit hyperactivity with a prevalence rate of 20–40% (Weissbluth et al., 1983; Ali, Pitson and Stradling, 1993). Conversely, children with ADHD showed a high prevalence rate of snoring (Chervin et al., 1997) and a co-diagnosis of ADHD has been reported in 8–12% of children with OSAS (O'Brien and Gozal, 2002).

A few studies have documented that children with sleep disorders tend to have behavioural problems similar to those observed in children with ADHD. A survey of 782 children documented daytime sleepiness, hyperactivity, and aggressive behaviour in children who snored, with 27% and 38% of children at high risk for a sleep or breathing disorder displaying clinically significant levels of inattention and hyperactive behaviour, respectively (Ali, Pitson and Stradling, 1994).

At 3 years of age children with persistent sleep problems (n = 308) were more likely to have behaviour problems, especially tantrums and behaviour management problems (Zuckerman, Stevenson and Bailey, 1987).

In a study of 16 children with a mean age of 12+/-4 years suffering from chronic pain due to juvenile rheumatoid arthritis and secondary poor sleep, polysomnographic recordings showed poorer night-time sleep, longer afternoon naptime and more daytime sleepiness than normal values from the literature (Zamir et al., 1998). In a school survey of children aged 9–12 years (n = 1000), those with poor sleep (insomnia for more than 6 months) had poorer school performance, defined as failure to comply with expected grades, than good sleepers. Their learning problems were tentatively attributed to the long-term effect of poor sleep (Kahn et al., 1989).

A questionnaire administered to children aged 4–12 years (n = 472) showed a relation between sleep problems and tiredness during the day (Stein et al., 2001).

In children aged 9–12 years (n = 77), shortening sleep by one hour was associated with reduced alertness and significant lowering of neurobehavioural functioning (Sadeh, Gruber and Raviv, 2003). In school-age children (n = 140) recorded at home with an actigraph, a significant relation was shown between the presences of fragmented sleep, daytime sleepiness and lower performance in neurobehavioural functioning evaluated by various performance tests (Sadeh, Gruber and Raviv, 2000). These children also had higher rates of behavioural problems, as reported by their parents (Sadeh, Gruber and Raviv, 2002).

In Finland, children aged 7–12 years (n = 49) were interviewed together with their parents and schoolteachers and recorded for 72 hours with a belt-worn activity monitor during weekdays. The decreased amount of sleep was associated with symptoms such as aggressive and delinquent behaviour, attention, social and somatic problems. The findings of this research were better associated with the teachers' than the parents' reports, suggesting that parents may be unaware of their child's sleep deficiencies as the behavioural problems may be more evident at school than at home (Aronen et al., 2000).

A prospective long-term study conducted in Sweden on 2518 children revealed that within a subgroup of 27 children with severe and chronic sleep problems, 7 children developed symptoms that met the criteria for ADHD by the age of 5.5 years (Thunström, 2002). Compared to the other children with sleep problems, these subjects had more frequent psychosocial problems in the family, bedtime struggles and long sleep latency at bedtime.

A population-based, cross-sectional questionnaire survey was conducted in Massachusetts on 30 195 children aged 5 years (Gottlieb et al., 2003). Children described by their parents as having sleep-disordered breathing (snoring, noisy breathing, apnoea) were significantly more likely to have daytime sleepiness and problem behaviours, including hyperactivity, inattention and aggressiveness (all with an odds ratio >2.0). These problem behaviours were suggestive of ADHD.

Similar findings were found in a group of children aged 5–7 years with periodic limb movement disorder who were studied polygraphically and their recording compared with those of age-matched children with ADHD. Their repeated sleep fragmentation resulting from the periodic limb movement disorder favoured the development of symptoms similar to those seen in ADHD (Crabtree et al., 2003).

The parents of a group of children with an average age of 8.6 years (range 2–17 years) reported that their children had difficult behaviours on the day that followed a 4-hour night-time sleep restriction (Wassmer et al., 1999). In one study, a 2-hour sleep reduction induced by delayed bedtime has been shown to increase daytime sleepiness, mainly during morning hours (Ishihara and Miyke, 1998; Ishihara, 1999).

Following one night of 4 hours of sleep deprivation imposed on children (aged 11–13 years), a decrease in performance tests has been observed (Carskadon, Harvey and Dement, 1981a).

Following one night's sleep loss, adolescents showed increased sleepiness, fatigue and reaction time. They selected less difficult academic tasks during a set of tests, but the percentages of correct responses were comparable to those seen following a normal night's sleep (Engle-Friedman et al., 2003).

Another study has been conducted on 82 children, aged 8–15 years. They were assigned an optimized, 10-hour night of sleep, or a restricted 4-hour night of sleep. Sleep restriction was associated with shorter daytime sleep latency, increased subjective sleepiness, and increased sleepy and inattentive behaviours, but was not associated with increased hyperactive-impulsive behaviour or impaired performance in tests of response inhibition and sustained attention (Fallone et al., 2001).

#### *2.3.1.8 Mental health*

A recent longitudinal study on the outcomes of early life sleep problems and their relation to behaviour problems in early childhood stressed the importance of studying the natural history of sleep problems and their consequences in order to identify whether persistent or recurrent sleep problems at age 3–4 years are associated with co-morbidities such as child behaviour problems, maternal depression and poor family functioning (Peiyoong, Hiscock and Wake, 2003).

The authors found that night waking at 3–4 years of age continued to be common. Seventy eight percent of mothers reported that their child awoke during the night at least once during the week, and of these waking children, 43% were reported to have awakenings 4 or more nights per week. Children with early sleep problems had significantly higher mean scores on internalizing and externalizing behaviour and the aggressive behaviour and somatic problems subscales of the Child Behavior Checklist (CBCL).

It has been noted that within groups of children and adolescents with psychiatric, behavioural or emotional problems, rates of sleep disorders are elevated (Sadeh et al., 1995). On the other hand, children and adolescents with disturbed sleep report more depression, anxiety, irritability, fearfulness, anger, tenseness, emotional instability, inattention and conduct problems, drug use and alcohol use.

Only a few longitudinal studies in adolescents have evaluated the impact of insomnia on future functioning. In a large sample of 11–17-year-old adolescents, followed for one year, using symptoms of DSM-IV criteria for insomnia, Roberts, Roberts and Chen (2002) found that nearly 18% of the youths 11–17 years of age reported non-restorative sleep almost every day in the past month, over 6% reported difficulty in initiating sleep, over 5% waking up frequently during the night, another 3% had early-morning awakening almost every day, over 7% reported daytime fatigue and 5% daytime sleepiness. Combining "often" and "almost every day" response categories dramatically increases prevalence, ranging from 60% for non-restorative sleep to 23% for daytime fatigue and 12% for waking up at night with difficulty going back to sleep. The re-evaluation of the sample at follow-up showed that insomnia predicted two indicators of psychological functioning: self-esteem and symptoms of depression (Roberts, Roberts and Chen, 2002).

#### *2.3.1.9 Growth impairment*

Failure to thrive is a well-known complication of disturbed sleep and childhood OSAS. The cause of poor growth is not known, although many different reasons have been implicated: (a) poor caloric intake associated with adenotonsillar hypertrophy; (b) excessive caloric expenditure secondary to increased work of breathing; (c) abnormal growth hormone (GH) release secondary to loss of deep non-REM sleep. The relative roles of these factors are unclear (Marcus et al., 1994; ATS, 1999). Circulating concentrations of insulin-like growth factor-I (IGF-I) and IGF-binding protein 3 (IGFBP-3) reflect mean daily GH levels, and seem to correlate well with physiological changes in GH secretion. In the operated children with initial OSAS a highly significant reduction in the apnoea-hypopnea index (AHI) was found and both the IGF-I and the IGFBP-3 concentrations increased significantly. GH is released in a pulsatile fashion; the initial secretion is synchronized with the onset of SWS and strongly correlated with slow-wave activity, within 90 to 120 minutes from the onset of sleep (Nieminen et al., 2002). In OSAS children, the sleep architecture is relatively well-preserved, but the microstructural alteration of SWS due to micro-arousals induced by respiratory disturbance could play a role in the abnormal profile of GH secretion.

#### *2.3.1.10 Cardiovascular complications*

Children with OSAS had a significantly higher diastolic blood pressure (BP) than those with primary snoring. Multiple linear regression showed that BP could be predicted by apnoea index, body mass index and age. The aetiology of OSAS-related hypertension is thought to be due to a number of factors, particularly sympathetic nervous system activation secondary to arousal and, to a lesser degree, hypoxaemia.

Although cortical arousals at the termination of obstructive apnoeas are less common in children than in adults, children may manifest signs of subcortical arousal, including autonomic changes such as tachycardia. It is therefore possible that these subcortical arousals are associated with elevations of BP. A correlation between the frequency of obstructive apnoea and BP, but no correlation between SaO2 (arterial oxygen saturation) and BP was found, suggesting that respiratory-related subcortical arousals rather than hypoxaemia may be a major determinant of BP elevation in children (Marcus, Greene and Carroll, 1998). Similarly to BP variations induced by OSAS, other studies suggest that chronic exposure to environmental noise during sleep could contribute to a permanent increases in BP in otherwise healthy individuals and that no habituation to noise was apparent over three consecutive sleep sessions (Carter et al., 2002). This is further elaborated in Chapter 4, section 4.5.

*2.3.1.11 Risk of accidents*

Only one study was found that evaluated the association between sleep and duration of wakefulness and childhood unintentional injury (Valent, Brusaferro and Barbone, 2001).

Two hundred and ninety-two injured children who attended the Children's Emergency Centre in Udine, Italy, or their parents were interviewed following a structured questionnaire. The sleeping time and wakefulness of the child was assessed retrospectively for each of the 48 hours before injury. For each child, the authors compared the 24 hours immediately before the injury (hours 1–24; case period) with hours 25–48 (control period).

Overall, more children had longer hours of sleep during the control period than during the case period. A direct association between injury risk and sleeping less than 10 hours was found among boys (RR: 2.33; 95% CI: 1.07–5.09) but not among girls (RR: 1.00; 95% CI: .29–3.45). The study also found a direct association between injury occurring between 16.00 and midnight, and being awake for at least 8 hours before injury occurred (both sexes, RR: 4.00; 95% CI: 1.13–14.17). Sleeping less than 10 hours a day was associated with an 86% increase in injury risk. A significantly increased risk did not emerge in all subgroups of patients but it was evident among children aged 3–5 years, boys in particular. A fourfold increase in injury risk was also associated with being awake for at least 8 hours among males only. These findings demonstrated that inadequate sleep duration and lack of daytime naps are transient exposures that may increase the risk of injury among children. Results of a study on sleep disturbance and injury risk in young children show inadequate sleep duration and lack of daytime naps. A lack of daytime naps means transient exposures that may increase the risk of injury among children. Among children (boys in particular) aged 3–5 years, sleeping less than 10 hours a day was associated with an 86% increase in injury risk. A fourfold increase in injury risk was also associated with being awake for at least 8 hours.

Daytime sleepiness in children is often manifested by externalizing behaviours noted by parents or teachers, such as increased activity levels, aggression, impulsivity, as well as by poor concentration, instantiation irritability and moodiness (Fallone, Owens and Deane, 2002).

Analysing attendance at school, data show that accidents took place at school (25.6%) and at home (22.0%), and statistics show that there is a highly significant greater total accident rate among boys than among girls. The most frequent injuries happening at school are fractures and dislocation of joints, head injuries being more common among school injuries compared with spare-time injuries. Most injuries occurred when children were in sports areas and it is noteworthy that 25% of all injuries were caused through intentional violence by other pupils.

*2.3.1.12 Use of sleeping pills*

Several studies demonstrated that the use of sleeping pills is common among children and that paediatricians are prone to prescribe these medications. Twenty-five percent of firstborn infants had been given "sedatives" by 18 months (Ounsted and Hendrick, 1977). A research study into parental reports of 11 000 preschool children showed that 12% took psychoactive drugs, most commonly for sleep: 39% daily and 60% intermittently for 1–2 years (Kopferschmitt et al., 1992). Another study (Trott et al., 1995) revealed that 35% of prescriptions for children less than a year old were for sleep disturbances and that sleep disturbances were also the most common reason for prescribing medications to preschool children (23%). Two French surveys on adolescents showed that 10–12% of the respondents reported use of prescription or over-the-counter drugs for sleep disturbances (Patois, Valatz and Alperovitch, 1993; Ledoux, Choquet and Manfredi, 1994). Recently it has been reported that of 671 community-based United States paediatricians, 75% had recommended over-the-counter and 50% prescription medicines for insomnia during the past 6 months (Owens, Rosen and Mindell, 2003). In addition, an Italian survey showed that pharmacological treatment for sleep problems was prescribed during the past 6 months by 58.54% of paediatricians and by 61.21% of child neuropsychiatrists (Bruni et al., 2004).

## 2.3.2 BASIC INDIVIDUAL FACTORS: GENDER AND AGE

Gender shows itself to be an important predictor of disturbed sleep in virtually all epidemiological studies (Karacan et al., 1976; Bixler, Kales and Soldatos, 1979; Ancoli-Israel and Roth, 1999; Leger et al., 2000; Sateia et al., 2000). On the other hand, there does not seem to be much of a difference in polysomnographical parameters between males and females, except for the former losing SWS with increasing age and having slightly reduced sleep efficiency also with increasing age (Williams, Karacan and Hursch, 1974; Hume, Van and Watson, 1998). Ehlers and Kupfer (1997) timed the start of differences between genders to between 20 and 40 years. Spectral analysis also indicates slightly larger amounts of low frequency activity in females (Dijk, Beersma and Bloem, 1989; Dijk, Beersma and Van den Hofdakker, 1989). In addition, men seem to run a higher risk of morbidity and mortality related to sleep problems than women (Nilsson et al. 2001). The inconsistency between polysomnography and subjective measures has not been resolved but it may be important that most polysomnographical studies have controlled for anxiety and depression. Thus, it is conceivable that the higher level of subjective complaints in women reflects a higher prevalence of anxiety. The latter is a speculation, however. A confounding factor in gender comparisons is that phases in female biological cycles are also usually controlled for in polysomnographical studies, meaning that potential effects of, for example, menstruation, may not receive their proper weight. A recent review has gone through the literature in this area (Moline et al., 2003). It found that the luteal phase of the menstrual cycle is associated with subjective sleep problems, but polysomnographical studies have not supported this. Pregnancy affects sleep negatively as early as in the first trimester and the effects mainly involve awakenings and difficulties getting back to sleep. Napping is a frequent coping method. The post-partum period is often associated with severe sleep disruption, mainly due to feeding and comforting the infant. There seems to be some relation between sleep disruption and post-partum mood, but nothing is known about the causal relations. Menopause seems to involve disrupted sleep in relation to hot flushes, depression/anxiety and sleep-disordered breathing. Oestrogen is associated with improved sleep quality but it is not clear whether the effects are due to a reduction of hot flushes. Oestrogen also improves sleep-disordered breathing.

With respect to background factors, age is an established predictor of disturbed sleep (Karacan et al., 1976; Bixler, Kales and Soldatos, 1979; Ancoli-Israel and Roth, 1999; Ribet and Derriennic, 1999; Leger et al., 2000; Sateia et al., 2000). Interestingly, however, older age may be related to a lower risk of impaired awakening (Åkerstedt et al., 2002c), that is, in this study it was easier to wake up and one felt better rested with increasing age, while at the same time sleep quality was lower. The increased risk of disturbed sleep is consistent with the increasingly strong interference of the circadian morning upswing of the metabolism with increasing age (Dijk and Duffy, 1999). Thus sleep maintenance is impaired and when sleep is interrupted "spontaneously", the awakening is, by definition, easily accomplished and will be lacking in inertia. This ease of awakening may be interpreted as "being well-rested", and obviously the need for sleep is not great enough to prevent an effortless transition into wakefulness.

In addition, sleep homeostasis seems to be weakened with age in the sense that sleep becomes more fragmented and SWS or power density in the delta bands decrease (Williams, Karacan and Hursch, 1974; Bliwise, 1993; Dijk et al., 1999). As mentioned above, the effects are more pronounced in males, a fact that may be linked to reduced levels of growth hormone and testosterone.

### 2.3.3 PERSONS EXPOSED TO STRESSORS AS A RISK GROUP

A number of epidemiological studies point to a strong link between stress and sleep (Åkerstedt, 1987; Urponen et al., 1988; Ancoli-Israel and Roth, 1999). In fact, stress is considered the primary cause of persistent psychophysiological insomnia (Morin, Rodrigue and Ivers, 2003). That stress can affect proper sleep seems obvious, but Vgontzas et al. (2001) at Pennsylvania State University College of Medicine have found another reason why middle-aged men may be losing sleep. It is not just because of what they worry about; rather, it is due to "increased vulnerability of sleep to stress hormones".

As men age, it appears they become more sensitive to the stimulating effects of corticotropin-releasing hormones (CRH). When both young and middle-aged men were administered CRH, the older men remained awake longer and slept less deeply. (People who don't get enough of this "slow-wave" sleep may be more prone to depression.)

The increased prevalence of insomnia in middle age may, in fact, be the result of deteriorating sleep mechanisms associated with increased sensitivity to arousal-producing stress hormones, such as CRH and cortisol. In another study, the researchers compared patients with insomnia to those without sleep disturbances. They found that "insomniacs with the highest degree of sleep disturbance secreted the highest amount of cortisol, particularly in the evening and night-time hours", suggesting that chronic insomnia is a disorder of sustained hyperarousal of the body's stress response system. Also, recent epidemiological studies have shown a connection between disturbed sleep and later occurrence of stress-related disorders such as cardiovascular diseases (Parish and Shepard, 1990; Nilsson et al., 2001;

Leineweber et al., 2003) and diabetes type II (Nilsson et al., 2002). The mechanism has not been identified but both lipid and glucose metabolisms are impaired in relation to experimentally reduced sleep (Åkerstedt and Nilsson, 2003). Burnout is another result of long-term stress and a growing health problem in many industrialized countries (Weber and Jaekel-Reinhard, 2000). In Sweden, burnout is thought to account for most of the doubling of long-term sickness absence since the mid-1990s (RFV, 2003). The characteristic clinical symptoms of the condition are excessive and persistent fatigue, emotional distress and cognitive dysfunction (Kushnir and Melamed, 1992; Melamed, Kushnir and Sharom, 1992). Self-reports of disturbed sleep are pronounced in subjects scoring high on burnout (Melamed et al., 1999; Grossi et al., 2003). Since shortened and fragmented sleep is related to daytime sleepiness and impaired cognitive performance (Bonnet, 1985, 1986a, 1986b; Dinges et al., 1997; Gillberg and Åkerstedt, 1998; Åkerstedt, 1990), disturbed sleep might provide an important link between the state of chronic stress and the complaints of fatigue and cognitive dysfunction seen in burnout.

Partinen, Eskelinen and Tuomi (1984) investigated several occupational groups and found disturbed sleep to be most common among manual workers and much less so among physicians or managing directors. Geroldi et al. (1996) found in a retrospective study of older individuals (above the age of 75) that former white-collar workers reported better sleep than blue-collar workers. Kupperman et al. (1995) reported fewer sleep problems in subjects satisfied with work.

In what seems to be the most detailed study so far, Ribet and Derriennic (1999) studied more than 21 000 subjects in France, using a sleep disturbance index and logistic regression analysis. They found that shift work, a long working week, exposure to vibrations, and "having to hurry" appeared to be the main risk factors, controlling for age and gender. Disturbed sleep was more frequent in women (Karacan et al., 1976; Bixler, Kales and Soldatos, 1979; Ancoli-Israel and Roth, 1999) and in higher age groups.

The particular stressor linked to disturbed sleep may be linked to pressure of work (Urponen et al., 1988; Ancoli-Israel and Roth, 1999; Ribet and Derriennic, 1999; Åkerstedt et al., 2002b). The demands of work are a classical work stress factor and, when combined with low decision latitude, a relation has been shown to cardiovascular diseases (Theorell et al., 1998) and absenteeism (North et al., 1996). Interestingly, when "persistent thoughts about work" was added to the regression in the study by Åkerstedt et al. (2002b) this variable took over part of the role of work demands as a predictor. This suggests that it may not be work demands per se that are important, but rather their effect on unwinding after work. In two studies it has been demonstrated that even moderate worries about being woken during the night or having a negative feeling about the next day will affect sleep negatively, mainly reducing SWS (Torsvall and Åkerstedt, 1988; Kecklund and Åkerstedt, 1997). On the other hand, there is very little data to connect real life stress with polysomnographical indicators of disturbed sleep. Most studies have used rather innocuous and artificial stressors in a laboratory environment. Field studies of stress are virtually lacking, with some exceptions (Hall et al., 2000).

A lack of social support at work is a risk indicator for disturbed sleep (Åkerstedt et al., 2002b). Few previous data of this type have been found, but poor (general) social support has been associated with sleep complaints in Vietnam veterans (Fabsitz, Sholinsky and Goldberg, 1997). On the other hand, there are several studies indicating a close connection with poor social support for, for example, cardiovascular diseases (Arnetz et al., 1986) or muscle pain (Ahlberg-Hultén, Theorell and Sigala, 1995).

Interestingly, the metabolic changes seen after sleep curtailment in normal sleepers or in insomniacs and sleep apnoeics are similar to those seen in connection with stress. That is, lipid and glucose metabolisms are increased, as are cortisol levels (Spiegel, Leproult and van Cauter, 1999; Vgontzas et al., 2000, 2001). Together with the prospective links to stress-related diseases such as diabetes type II, to cardiovascular diseases as discussed above and with mortality (Kripke et al., 1979, 2002; Åkerstedt et al., 2002a; Dew et al., 2003), the findings could suggest that disturbed sleep may be an important mediator in the development of stress-related diseases.

### 2.3.4 SHIFT WORK AS A RISK FACTOR FOR SLEEP DISTURBANCE AND HEALTH EFFECTS

The dominating health problem reported by shift workers is disturbed sleep and wakefulness. At least three quarters of the shift working population is affected (Åkerstedt, 1988). When comparing individuals with a very negative attitude to shift work with those with a very positive one, the strongest discriminator seems to be the ability to obtain sufficient quality of sleep during the daytime (Axelsson et al., 2004). EEG studies of rotating shift workers and similar groups have shown that day sleep is 1–4 hours shorter than night sleep (Foret and Lantin, 1972; Foret and Benoit, 1974; Matsumoto, 1978; Tilley, Wilkinson and Drud, 1981; Torsvall et al., 1989; Mitler et al., 1997). The shorter time is due to the fact that sleep is terminated after only 4–6 hours without the individual being able to return to sleep. The sleep loss is primarily taken out of stage 2 sleep and stage REM sleep (dream sleep). Stages 3 and 4 ("deep" sleep) do not seem to be affected. Furthermore, the time taken to fall asleep (sleep latency) is usually shorter. Night sleep before a morning shift is also reduced but the termination is through artificial means and the awakening usually difficult and unpleasant (Dahlgren, 1981a; Tilley et al., 1982; Åkerstedt, Kecklund and Knutsson, 1991; Kecklund, 1996).

Interestingly, day sleep does not seem to improve much across a series of night shifts (Foret and Benoit, 1978; Dahlgren, 1981b). It appears, however, that night workers sleep slightly better (longer) than rotating workers on the night shift (Kripke, Cook and Lewis, 1971; Bryden and Holdstock, 1973; Tepas et al., 1981). The long-term effects of shift work on sleep are rather poorly understood. However, Dumont, Montplaisir and Infante-Rivard (1988) found that the amount of sleep/wake and related disturbances in present day workers were positively related to their previous experience of night work. Guilleminault et al. (1982a) found an over-representation of former shift workers with different clinical sleep/wake disturbances appearing at a sleep clinic. Recently, we have shown that in pairs of twins with different night work exposure, the exposed twin reports somewhat deteriorated sleep quality and health after retirement (Ingre and Åkerstedt, 2004).

The main reason for short daytime sleep is the influence exerted by the circadian rhythm. The more sleep is postponed from the evening towards noon next day, the more truncated it becomes and when noon is reached the trend reverts (Foret and Lantin, 1972; Åkerstedt and Gillberg, 1981). Thus, sleep during the morning hours is strongly interfered with, despite the sizeable sleep loss that, logically, should enhance the ability to maintain sleep (Czeisler et al., 1980). Also, homeostatic influences control sleep. For example, the expected 4–5 hours of daytime sleep, after a night spent awake, will be reduced to 2 hours if a normal night's sleep precedes it and to 3.5 hours if a 2-hour nap is allowed (Åkerstedt and Gillberg, 1986). Thus, the time of sleep termination depends on the balance between the circadian and homeostatic influences. The circadian homeostatic regulation of sleep has also been demonstrated in great detail in studies of forced or spontaneous desynchronization under conditions of temporal isolation and ad lib sleeping hours (Czeisler et al., 1980; Dijk and Czeisler, 1995).

*2.3.4.1 Alertness, performance and safety*

Night-oriented shift workers complain as much of fatigue and sleepiness as they do about disturbed sleep (Åkerstedt, 1988). The sleepiness is particularly severe on the night shift, hardly appears at all on the afternoon shift and is intermediate on the morning shift. The maximum is reached towards the early morning (05.00–07.00). Frequently, incidents of falling asleep occur during the night shift (Prokop and Prokop, 1955; Kogi and Ohta, 1975; Coleman and Dement, 1986). At least two thirds of the respondents report that they have experienced involuntary sleep during night work.

Ambulatory EEG recordings verify that incidents of actual sleep occur during night work in, for example, process operators (Torsvall et al., 1989). Other groups, such as train drivers or truck drivers show clear signs of incidents of falling asleep while driving at night (Caille and Bassano, 1977; Torsvall and Åkerstedt, 1987; Kecklund and Åkerstedt, 1993). This occurs towards the second half of the night and appears as repeated bursts of alpha and theta EEG activity, together with closed eyes and slow undulating eye movements. As a rule the bursts are short (1–15 seconds) but frequent, and seem to reflect lapses in the effort to fend off sleep. Approximately a quarter of the subjects recorded show the EEG/EOG patterns of fighting with sleep. This is clearly a larger proportion than what is found in the subjective reports of episodes of falling asleep.

As may be expected, sleepiness on the night shift is reflected in performance. One of the classics in this area is the study by Bjerner, Holm and Swensson (1955) who showed that errors in meter readings over a period of 20 years in a gas works had a pronounced peak on the night shift. There was also a secondary peak during the afternoons. Similarly, Brown (1949) demonstrated that telephone operators connected calls considerably slower at night. Hildebrandt, Rohmert and Rutenfranz (1974) found that train drivers failed to operate their alerting safety device more often at night than during the day. Most other studies of performance have used laboratory type tests and demonstrated, for example, reduced reaction time or poorer mental arithmetic on the night shift (Tepas et al., 1981; Tilley et al., 1982). Flight simulation studies have furthermore shown that the ability to "fly" a simulator (Klein, Bruner and Holtman, 1970), or to carry out a performance test (Dawson and Reid, 1997) at night may decrease to a level corresponding to that after moderate alcohol consumption (>0.05% blood alcohol) Interestingly, Wilkinson et al. (1989) demonstrated that reaction time performance on the night shift (nurses) was better in permanent than rotating shift workers.

If sleepiness is severe enough, interaction with the environment will cease and if this coincides with a critical need for action an accident may ensue. Such potential performance lapses due to night work sleepiness were seen in several of the train drivers discussed earlier (Torsvall and Åkerstedt, 1987). The transport area is where most of the available accident data on night shift sleepiness has been obtained (Lauber and Kayten, 1988). Thus, Harris (1977) and Hamelin (1987) demonstrated that single vehicle accidents have by far the greatest probability of occurring at night.

So do fatigue-related accidents (Reyner and Horne, 1995) but also most other types of accidents, for example head-on collisions and rear-end collisions (Åkerstedt, Kecklund and Horte, 2001). The National Transportation Safety Board ranks fatigue as one of the major causes of heavy vehicle accidents (NTSB, 1995).

For conventional industrial operations very little relevant data is available but fatal work accidents show a higher risk in shift workers (Åkerstedt et al., 2002a) and accidents in the automotive industry may exhibit night shift effects (Smith, Folkard and Poole, 1994). An interesting analysis has been put forward by the Association of Professional Sleep Societies' Committee on Catastrophes, Sleep and Public Policy (Mitler et al., 1988). Their consensus report notes that the nuclear plant meltdown at Chernobyl occurred at 01.35 and was due to human error (apparently related to work scheduling). Similarly, the Three Mile Island reactor accident occurred between 04.00 and 06.00 and was due not only to the stuck valve that caused a loss of coolant water but, more importantly, to the failure to recognize this event, leading to the near meltdown of the reactor. Similar incidents, although with the ultimate stage being prevented, occurred in 1985 at the Davis Besse reactor in Ohio and at the Rancho Seco reactor in California. Finally, the committee also states that the NASA Challenger space shuttle disaster stemmed from errors in judgement made in the early morning hours by people who had had insufficient sleep (through partial night work) for days prior to the launch. Still, there is very limited support for the notion that shift work outside the transport area actually carries a higher overall accident risk.

As with sleep, the two main factors behind sleepiness and performance impairment are circadian and homeostatic factors. Their effects may be difficult to separate in field studies but are clearly discernible in laboratory sleep deprivation studies (Fröberg et al., 1975) as well as in studies of forced desynchronization (Dijk, Duffy and Czeisler, 1992). Alertness falls rapidly after awakening but gradually levels out as wakefulness is extended. The circadian influence appears as a sine-shaped superimposition upon this exponential fall in alertness. Space does not permit a discussion of the derivation of these functions, but the reader is referred to Folkard and Åkerstedt (1991) in which the "three-process model of alertness regulation" is described. This model has been turned into computer software for predicting alertness and performance and to some extent accident risk.

#### 2.3.4.2 *Health effects*

Gastrointestinal complaints are more common among night shift workers than among day workers. A review of a number of reports covering 34 047 persons with day or shift work found that ulcers occurred in 0.3–0.7% of day workers, in 5% of people with morning and afternoon shifts, in 2.515% of persons with rotating shift systems with night shifts, and in 10–30% of ex-shift workers (Angersbach et al., 1980). Several other studies have come to similar conclusions (Thiis-Evensen, 1958; Segawa et al., 1987; Harrington, 1994). Other gastrointestinal disorders, including gastritis, duodenitis and dysfunction of the digestive system are more common in shift workers than in day workers (Koller, 1983).

The pathophysiologic mechanism underlying gastrointestinal disease in shift workers is unclear, but one possible explanation is that intestinal enzymes and intestinal mobility are not synchronized with the sleep/wake pattern. Intestinal enzymes are secreted according to the circadian rhythm, and shift workers' intake of food is irregular compared with intestinal function (Suda and Saito, 1979; Smith, Colligan and Tasto, 1982). A high nightly intake of food may be related to increased lipid levels (Lennernås, Åkerstedt and Hambraeus, 1994) and eating at the circadian low point may be associated with altered metabolic responses (Hampton et al., 1996). In addition, reduced sleep affects lipid and glucose metabolism (Spiegel, Leproult and van Cauter, 1999).

A number of studies have reported a higher incidence of cardiovascular disease, especially coronary heart disease, in male shift workers than in men who work days (for review see Kristensen, 1989; Boggild and Knutsson, 1999). A study of 504 paper mill workers followed for 15 years found a dose–response relationship between years of shift work and incidence of coronary heart disease in the exposure interval 1–20 years of shift work (Knutsson et al., 1986). A study of 79 000 female nurses in the United States gave similar results (Kawachi et al., 1995) as did a study with more than 1 million Danish men (Tüchsen, 1993) and a cohort of Finnish workers (Tenkanen et al.,1997). As with gastrointestinal disease, a high prevalence of smoking among shift workers might contribute to the increased risk of coronary heart disease, but smoking alone cannot explain the observed excess risk (Knutsson, 1989b). Another possibility is disturbances of metabolic parameters such as lipids and glucose for which there is some support as discussed above.

Only a few studies have addressed the issue of pregnancy outcome in shift workers. In one study of laboratory employees, shift work during pregnancy was related to a significantly increased risk of miscarriage (RR: 3.2) (Axelsson, Lutz and Rylander, 1984). Another study of hospital employees also demonstrated an increased risk of miscarriage (RR: 1.44, 95% CI: 0.83–2.51) (Axelsson and Rylander, 1989). Lower birth weight in infants of mothers who worked irregular hours has been reported (Axelsson and Rylander, 1989; Nurminen, 1989). No teratogenic risk associated with shift work was reported (Nurminen, 1989).

The mortality of shift and day workers was researched by Taylor and Pocock (1972), who studied 8603 male manual workers in England and Wales between 1956 and 1968. Day, shift, and ex-shift workers were compared with national figures. The Standardized Mortality Ratio (SMR) can be calculated from observed and expected deaths reported in the paper. SMRs for deaths from all causes were 97, 101 and 119 for day, shift, and ex-shift workers respectively. Although the figures might indicate an increasing trend, the differences were not statistically significant. However, the reported SMR close to 100 is remarkable because the reference population was the general male population. Most mortality studies concerned with occupational cohorts reveal SMRs lower than 100, implying a healthy workers' effect (Harrington, 1978). The same study showed a significantly increased incidence of neoplastic disease in shift workers (SMR 116). A Danish study of 6000 shift workers failed to demonstrate any excess mortality in shift workers (Boggild et al., 1999). Not much evidence exists on the connection between shift work and cancer. The mortality study by Taylor and Pocock (1972) reported an increased incidence of neoplasms in shift workers compared with the general population. A recent Danish case–control study reported an increased risk of breast cancer among 30–45-year-old women who worked mainly nights (Hansen, 2001). Among 75 000 nurses those with more than 15 years of night work showed an increased risk of colorectal cancer (Schernhammer et al., 2003). If the results are confirmed, a possible mechanism may be the low levels of the hormone melatonin, due to light exposure during the night with a subsequent suppression of melatonin.

Very few studies are available but Koller, Kundi and Cervinka (1978) found a prevalence of endocrine and metabolic disease of 3.5% in shift workers and 1.5% in day workers. Kawachi et al. (1995) found in a prospective study of shift workers that the age-standardized prevalence was 5.6% at 15 years of shift work experience compared with 3.5% for no exposure. Nagaya et al. (2002) found that markers of insulin resistance were more frequent in shift workers above the age of 50 than in day workers. Other indicators, such as body mass index, glucose levels and so forth, give a rather inconclusive impression as indicated in a review by Boggild and Knutsson (1999).

Another contributing factor to gastrointestinal diseases might be the association between shift work and smoking. A number of studies have reported that smoking is more common among shift workers (Angersbach et al., 1980; Knutsson, Åkerstedt and Jonsson, 1988). Studies concerned with alcohol consumption comparing day workers and shift workers have produced conflicting results (Smith, Colligan and Tasto, 1982; Knutsson, 1989a; Romon, Nuttens and Fievet, 1992), probably due to local cultural habits. One study, which used g-glutamyltransferase as a marker of alcohol intake, did not indicate that the shift workers had a higher intake of alcohol than the day workers (Knutsson, 1989a).

Sickness absence is often used as a measure of occupational health risks. However, sickness leave is influenced by many irrelevant factors and cannot be considered as a reliable measure of true morbidity. Studies on sickness absence in day and shift workers have revealed conflicting results and there is no evidence that shift workers have more sickness absence than day workers (for review, see Harrington, 1978).

#### *2.3.4.3 Conclusion*

Shift work or similar arrangements of work hours clearly affects sleep and alertness and there is a moderate risk of cardiovascular and gastrointestinal disease. Other diseases such as cancer or diabetes may be related to shift work but the evidence is as yet rather weak.
The present review suggests that the risk of disturbed sleep increases with age but there also seems to be a recent stress-related increase in sleep disturbance in young adults. The long-term health consequences are not yet understood.

The relation between gender and disturbed sleep is confusing. Females, as a rule, complain more of sleep problems, but do not exhibit any objective indications of more disturbed sleep, at least not among otherwise healthy women. With increasing age the sleep of males deteriorates whereas that of women is relatively well upheld. Pregnancy, however, is a period of increased risk of disturbed sleep, whereas the menstrual cycle and menopause show less evidence of sleep disturbance. Clearly there is a great need for longitudinal research on gender and sleep and, in particular, on the possible health consequences connected with pregnancy.

Stress due to work or family seems to be one of the major causes of disturbed sleep. The link to the risk of insomnia is well-established, but reduced sleep in itself seems to yield the same physiological changes as stress. This suggests that several of the major civilization diseases in Europe and the United States (diabetes, cardiovascular diseases and burnout) could be mediated via disturbed sleep. This link clearly warrants longitudinal studies with interventions.

Shift workers constitute a group that suffers from disturbed sleep for most of their occupational life. The reason is the interference of work hours with the normal timing of sleep. This leads to an increased risk of accidents, directly due to excessive sleepiness, but also to cardiovascular and gastrointestinal diseases, although it is not clear whether the latter effects are sleep related or due to circadian factors – or to a combination. Recent studies also suggest that breast cancer may result from shift work due to the effects of light on melatonin secretion. This still needs verification, however. Future research needs to identify countermeasures, the reasons for large individual differences in tolerance and the possible carcinogenic and other effects.

The conclusions above should be seen against the profound effects of reduced or fragmented sleep on the neuroendocrine (including glucose and lipid regulation) and immune systems as well as the effects on mortality, diabetes and cardiovascular disease.

### 2.3.5 CONCLUSION

Children, the elderly, pregnant women, people under stress and shift workers are vulnerable to (noise) disturbance of their sleep.

## 2.4 ACCIDENTS RELATED TO SLEEP QUALITY

As already stated in the earlier section on cardiovascular complications, children with disturbed sleep present cognitive dysfunction and behavioural disturbances, abnormal growth hormone release, increase of diastolic BP and an increased risk of accidents and use of sleeping pills.

Regarding sleep disturbance and accidents in adults, data show that 15–45% of all patients suffering from sleep apnoea, 12–30% of all patients suffering from narcolepsy and 2–8% of all patients suffering from insomnia have at least one accident (in a lifetime) related to sleepiness (statistics from the Stanford Sleep Disorders Clinic).

As already discussed in section 2.3.4, the biggest industrial catastrophes, such as the Three Mile Island, Bhopal, Chernobyl and Exxon Valdez disasters, have occurred during the night shift. The shift schedules, fatigue and sleepiness were cited as major contributing factors to each incident.

The LARES study (Large Analysis and Review of European housing and health Status) is one of the few studies analysing this issue directly. The results show that the likelihood of home accidents is significantly greater when the individual is tired all the time or most the time and there is an association between sleep disturbance and accidents, with 22% of those reporting an accident also reporting having their sleep disturbed during the previous four weeks.

The data available to document the impact of environmental noise on sleep deprivation and accidents are largely inadequate. There is no estimation of relative risk. Further research is needed in order to identify the accident-related burden of diseases attributable to noise during the night-time.

## 2.5 ANIMAL STUDIES

As pet owners know, cats sleep (most of the time it seems) and so do dogs. But do fish sleep? And flies? Yes, most animals sleep, and they even show the same phenomena as in humans; from deep sleep, dream sleep to sleep disorders. There are also many differences and weird behaviour, such as sleeping with only one half of the brain at a time (dolphins and ducks).

As Ising points out (Appendix 3), in animal experiments it is possible to assess the complete causal chain from noise exposure via physiological reactions and biological risk factors to morbidity or even mortality. However, a quantitative application of the results to humans is not possible. Instead, the method is useful in studying the pathomechanisms qualitatively. Rechtschaffen and Bergmann (1965) studied sleep deprivation in rats, showing that total sleep deprivation leads to mortality in 16 to 20 days. As the animals in the last stage died from microbial infection, Everson and Toth (2000) proceeded to show early infection of the lymph nodes and other tissues and hypothesized that daily sleep of some amount is necessary to maintain an intact immune system that will prevent bacterial invasion, a view that has been challenged.

Surprisingly, sleep in the common fruit fly – *Drosophila melanogaster* – has many similarities with mammalian sleep, including sleep deprivation leading to impaired performance. Genetic studies in fruit flies (Cirelli et al., 2005) led to mutant flies that can get by on 30% less sleep than their normal counterparts, thanks to a single mutation in one gene. While they sleep 30% less they show no immediate ill effects. The lifespan of the flies is, however, reduced by 30%.

These animal models certainly lead one to believe that sleep is a biological necessity, and tampering with it is dangerous for survival.

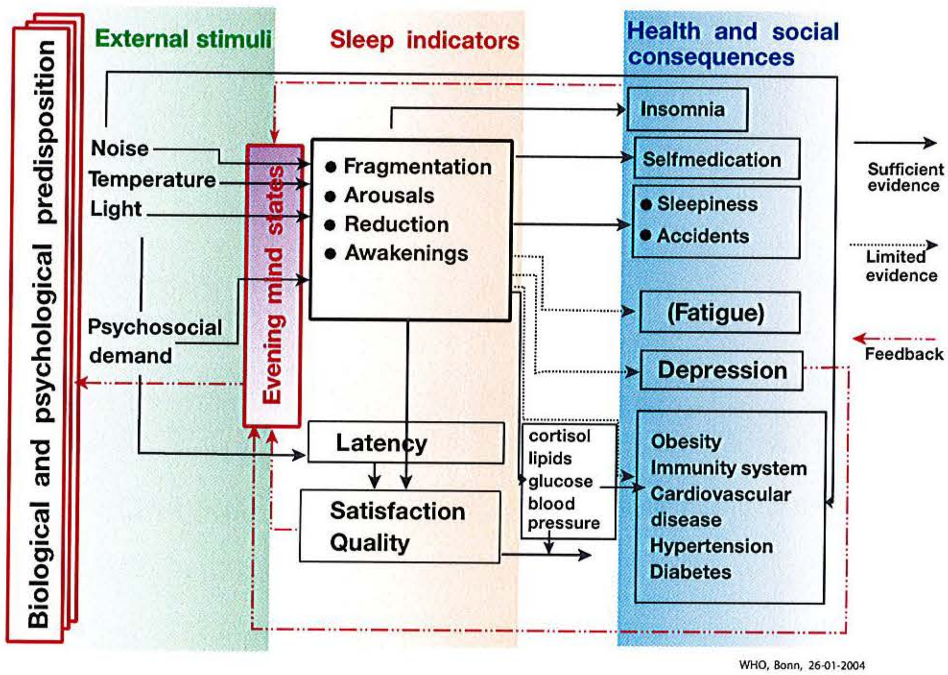
As Ising shows (Appendix 3) noise may play a role in this. Under stressful circumstances the death rate of rats is increased when noise levels are increased from "ambient" to $L_{eq}$=69 dB(A). Are noise and sleep deprivation stressors that both lead to early death? Is the noise effect due to sleep deprivation? A carefully planned study may sort this out. The question still remains, however, as to how far this is relevant to humans.

## 2.6 CONCLUSIONS

From the evidence presented so far it can be deduced that sleep is important for human functioning. Why exactly is less evident, but it is clear that disturbed sleep (either from internal factors or from external factors) leads to or is at least associated with fatigue, lower cognitive performance, depression, viral illness, accidents, diabetes, obesity and cardiovascular diseases. Animal experiments show that sleep deprivation shortens lifespan. The fact that – in comparison– relatively mild effects turn up in human sleep deprivation experiments could be due to the short period (about 10 days in controlled experiments) and the limitation to young and healthy adults. The central position of sleep in human functioning is summarized in Fig. 2.1. In this figure relations with sufficient evidence are indicated with solid lines, while relations for which limited evidence exists are indicated with interrupted lines. Feedback connections are in red and double-dotted.

The presence of feedback loops in the system is an indication that it may be difficult to prove direct cause–effect relations. One example is the relation between sleep quality and depression. They are strongly associated, but it is uncertain if depression causes bad sleep, or bad sleep causes depression (see also Chapter 4, section 4.8.11). This may also depend on one of the many other factors, so it could be different for different personality types.

**Fig.2.1**
**Expert view on the relations between sleep and health**




Impaired sleep is widely considered as a health problem per se, and this chapter has shown that there are many internal and external causes. In the next chapter the relation between noise and sleep quality is further unravelled.



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# CHAPTER 3

# EFFECTS OF NIGHT-TIME NOISE ON SLEEP

*Best travel tip: Never ever forget to pack ear plugs.*
*(Virginia Jealous, Lonely Planet author)*

## 3.1 SHORT-TERM EFFECTS OF TRANSPORTATION NOISE ON SLEEP WITH SPECIFIC ATTENTION TO MECHANISMS AND POSSIBLE HEALTH IMPACT

### 3.1.1 INTRODUCTION

In this section reactions to single events are presented. In Chapter 2 normal sleep and sleep disorders are described in medical terms, but here the focus is on the mechanisms underlying the relation between noise and sleep quality. How does a sound penetrate the brain and cause a disruption of sleep?

### 3.1.2 HOW NOISE INFLUENCES NORMAL SLEEP

Noise can induce changes in the EEG or in autonomic variables that are called arousals or phasic activations. Similar brief episodes of activity also occur without noise in normal sleep, and, more frequently, in sleep that is otherwise disturbed, for example by apnoea. Arousal during sleep is not a uniform concept and has been defined differently by different researchers. Commonly, the occurrence of alpha rhythms is required for EEG arousal. Depending on the additional requirements and on the length of time that the slower cortical rhythms are interrupted, arousals have been called, for instance, micro-arousal, minor arousal, EEG awakening or transient activation phases. EEG awakening requires an interruption of the sleep patterns of at least 15 seconds (half the period) when sleep staging is scored by periods of 30 seconds, but need not be experienced consciously. Because normal REM sleep is a state characterized by cerebral arousal with frequently occurring alpha rhythms, additional criteria are needed to define arousal from REM. The criteria used are increased heart rate, EMG, or irregular respiration. However, since the mechanisms of such autonomic responses appear to be at least partly different from the causal mechanisms of EEG arousal, such definitions seem to make arousal from sleep a heterogeneous concept that may not have simple relationships with noise exposure.

EEG arousals lasting at least 30 seconds have been found to occur as often as 4 times (95% CI: 1–15) per hour during sleep on average, while micro-arousals occurred 21 times (95% CI: 7–56) per hour (Mathur and Douglas, 1995). Since these figures are from a laboratory study, they almost certainly are higher than the figures that hold for the natural situation at home. Sleep pressure decreases the density of micro-arousals (Sforza, Jouny and Ibanez, 2000). While the number of EEG arousals (during sleep stages 1 and 2) increases with age (Mathur and Douglas, 1995; Boselli et al., 1998) possibly only for men (Hume, Van and Watson, 2003), their average length is stable and circa 15 seconds (Boselli et al., 1998). Also the threshold for auditory arousal decreases with age (Zepelin, McDonald and Zammit, 1984; Busby and Pivik, 1985; Busby, Mercier and Pivik, 1994) and towards the end of the night (Basner et al., 2004). Recovery after EEG awakenings takes longer for noise-induced awakenings than for spontaneous awakenings (Basner et al., 2004). The time required for falling asleep again depends on the sound level and especially for loud events this latency is considerably longer than after spontaneous awakenings. Thus, in general, noise-induced EEG awakenings are more disruptive than spontaneous awakenings and therefore will more often be experienced consciously and remembered afterwards. In common situations with aircraft overflight noise at home, (minor) arousals were found in 10.3% of the 64-second intervals without aircraft noise and this percentage was found to be increased by circa 4% up to 14.3% in intervals with an aircraft noise event (Hume, Van and Watson, 2003). Thus, in that particular (exposure) situation, about 1 in 24 aircraft overflights caused a (minor) arousal.

### 3.1.3 MECHANISMS

Activity in the auditory system up to the brainstem nucleus inferior colliculus occurs within 10 milliseconds after the onset of a sound. This early activity appears to be obligatory and is hardly affected by the state (sleeping or awake). Being asleep or awake does influence later activity. The auditory pathways proceed from the inferior colliculus to the thalamus and from there to the auditory cortex. The state (asleep or awake) affects the activity in the thalamocortical circuits, which occurs after 10–80 milliseconds. In particular, during SWS the transmission of auditory information through the thalamus is suppressed. This is not the case during REM sleep or when awake.

Thus, while in all (sleep) stages, sound activates the auditory system up to the inferior colliculus, the sound-induced activation of higher areas is suppressed in SWS. Therefore, further activation depending on those higher areas (for example, extracting meaning) is not likely to occur as a primary reaction to sound during SWS. For understanding arousal during SWS, it is important that the inferior colliculus and the earlier auditory nucleus of the lateral lemniscus, and also the (dorsal and ventral) cochlear nuclei project to reticular arousal system. Presumably, sound is always capable of arousing the sleeping subject through these connections. The ascending arousal system is heterogeneous and encompasses mono-aminergic, glutamatergic, and cholinergic nuclei that can directly or indirectly activate the thalamus and cortex. An important indirect route is the activation of the basal forebrain, which can activate the cerebral cortex through widespread, mainly cholinergic projections. The activation of the thalamus and cortex is indicated by an increase in EEG rhythm frequency and a reduction of the inhibition in the thalamic sensory relay nuclei. As a consequence of the latter effect, subsequent sound-induced activation may pass the thalamus and may be subject to more elaborate processing than initial sound. It can be speculated that sound in this way also reduces the threshold for somatosensory information that initiates body movements so that more body movements are observed when exposed to sound. The occurrence of habituation of cortical responses suggests an active role played by a part of the brain that blocks or at least limits the impact of the activated ascending pathways.

The parasympathetic autonomic nervous system seems to be responsible for the bradycardia observed in non-REM sleep and mainly in tonic REM sleep through the increase in vagal activity (Guazzi et al., 1968). The variability of heart rate in REM sleep could be placed under the same control, as vagotomy strongly reduced the heart rate instability (Baust and Bohnert, 1969). During falling asleep, respiration is unstable and alternates between hypo- and hyperventilation episodes. This respiration, called "periodic respiration" (Mosso, 1886), disappears when stable sleep occurs (stage 2). The main hypotheses concerning this periodic ventilation refer to metabolic control and chemoreceptor responses to levels of $PaCO_2$ and $PaO_2$ (Chapman et al., 1988). In stable non-REM sleep, respiration is regular in amplitude and frequency, although ventilation per minute is lower than during awakening. In REM sleep, respiration appears irregular with sudden variations in amplitude and frequency. This irregularity appears to be not modifiable by metabolic factors and, therefore, it is possibly linked to mechanisms leading to REM expression. The non-habituation of the cardiovascular responses would be explained by the absence of an inhibitory influence on the part of the arousal system that affects the centres regulating the autonomous response.

### 3.1.4 EEG RESPONSE

The sleep polygraph continuously records EEG activity, eye movement (EOG) and muscle tone (EMG). These data are used to classify sleep into various stages, and to assess times of falling asleep and waking up. Also, sleep variables such as total sleep time and total time spent in SWS (consisting of sleep stages 3 and 4, the stages of deep sleep) and in the REM stage (also called dream or paradoxical sleep) can be assessed on the basis of sleep polygraph recordings. Polygraphic indicators of responses to individual noise events are changes from a deeper to a less deep sleep and EEG awakening. Several field studies (Pearsons, Bennett and Fidell, 1973; Vernet, 1979; Vallet et al., 1983; Hume, Van and Watson, 2003; Basner et al., 2004) have been conducted regarding noise-induced changes in sleep stage and awakening using EEG recordings. Transition from a deep stage of sleep to a shallower sleep stage can be the direct consequence of a nocturnal noise event. Although not perceived by the sleeper, these transitions modify the sleep architecture and may reduce the amount of SWS (Carter, 1996; Basner et al., 2004) and the amount and rhythmicity of REM sleep may be markedly affected (Naitoh, Muzet and Lienhard, 1975; Thiessen, 1988). In addition to their results from a laboratory study, Basner et al. (2004) present results from a field study with valid data for 63 subjects (aged 18–65 years) with 15 556 aircraft noise events included in the final analyses. They established a curve that gives the probability of awakening as a function of $L_{Amax}$ with a model that assumed a background noise level just prior to the aircraft noise event of 27 dB(A). The $L_{Amax}$ threshold for noise-induced awakenings was found to be about 35 dB(A). Above this threshold the probability of noise-induced awakenings increases monotonically up to circa 10% when $L_{Amax}$ = 73 dB(A). This is the extra probability of awakening associated with the aircraft noise event, on top of the probability of awakening spontaneously in a 90 second interval.

Some arousals provoked by noise events are so intense that they induce awakening. Frequent awakening leads to sleep fragmentation and overall sleep disturbance. The noise threshold for awakening is particularly high in deep SWS (stages 3 and 4) while it is much lower in shallower sleep stages (stages 1 and 2). In REM sleep the awakening threshold is variable and depends on the significance of the stimulus. Total



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sleep time can be reduced by both a longer time to fall asleep and premature final awakening. It has been reported that intermittent noises with maximum noise levels of 45 dB(A) and above can increase the time taken to fall asleep by a few to 20 minutes (Öhrström, 1993). In the morning hours, the sleeper can be more easily awakened by ambient noise and has more difficulty going back to sleep because sleep pressure is progressively reduced with time (Rechtschaffen, Hauri and Zeitlin, 1966; Keefe, Johnson and Hunter, 1971).

Terzano et al. (1990, 1993) showed that with increasing intensity of sound pressure level (white noise at 45, 55, 65 and 75 dB(A), white noise induced a remarkable enhancement of cyclic alternating patterns (CAP)/non-REM, characterized by a linear trend from the lowest to the highest intensities, revealed by a significant increase in the CAP rate already at 45 dB(A). Noise decreased mainly SWS, REM and total sleep time, and increased waking after sleep onset, stage 1 non-REM and CAP rate (Terzano et al., 1993). For CAP/non-REM values between 45% and 60%, subjects generally recalled a moderate nocturnal discomfort and values of CAP/non-REM over 60% corresponded to a severe complaint.

This result corroborates previous findings described by Lukas (1972a) who reported that reactions less intense than a sleep stage change correlate better to the noise intensity than awakening reactions.

### 3.1.5 CARDIOVASCULAR RESPONSE

For sleeping persons, mean heart rate, mean systolic and diastolic BP and variability in heart rate are usually assessed. Indicators of responses to individual noise events are instantaneous changes in (variability of) heart rate and changes in systolic BP. Several field studies (Carter et al., 1994) have been conducted regarding momentary change in heart rate. Intermittent noise during sleep has been found to induce a biphasic cardiac response and a transient constriction of peripheral vessels together with a short phasic activation in the EEG, while no other behavioural effect can be seen (Muzet and Ehrhart, 1978). This biphasic cardiac response starts with an increase in heart rate, probably due to a phasic inhibition of the parasympathetic cardio-inhibitory centre, followed by a compensatory decrease due to a phasic decrease in orthosympathetic activity (Keefe, Johnson and Hunter, 1971; Muzet and Ehrhart, 1980). The vasoconstrictive response was reported to be due to the sympathetic peripheral stimulation provoked by the auditory reflex (Kryter and Poza, 1980). More recently, Carter et al. (2002) have shown that beat-by-beat BP changes can be induced by suddenly occurring noises. Although habituation in some effect parameters can occur in a few days or weeks, this habituation is not complete and the measured modifications of the cardiovascular functions remain unchanged over long periods of exposure time (Muzet and Ehrhart, 1980; Vallet et al., 1983). Most striking is that none of the cardiovascular responses show habituation to noise after a prolonged exposure, while subjective habituation occurs within a few days. In people that are used to sleep in a noisy surrounding, noise-induced changes in heart rate are dependent on the maximum sound level of a noise event, but not on the EEG sleep stage).

### 3.1.6 BODY MOVEMENT

Motility is the term used for accelerations of the body or body parts during movement. It is measured with actimeters, usually worn on the wrist in field research and the laboratory. Brink, Müller and Schierz (2006) describe a more sophisticated method which is based on the bed being placed on accelerometers. This allows the tracking of whole body movements.

Motility is related to many variables of sleep and health (Reyner, 1995; Reyner et al., 1995; Passchier-Vermeer et al., 2002). Clinical research shows that the sleep/wake cycle (assessed by polysomnography, EEG, EOG, EMG) passes through the 24-hour period synchronously with the rest/activity cycle (assessed by actimetry) (Borbely et al., 1981). A number of investigations have compared the results of polysomnographic recordings (number of EEG-awakenings during sleep period, duration of sleep period, sleep onset time, wake-up time) with results of actimetry. The correlation between actimetrically assessed duration of sleep period, sleep onset time, wake-up time and similar variables assessed with polysomnography was found to be very high (correlation coefficients between individual test results in the order of 0.8–0.9). Measures of instantaneous motility are the probability of motility and the probability of onset of motility in a fixed time interval, for example a 15-, 30- or 60-second interval. Increased instantaneous motility during sleep is considered to be a sensitive behavioural marker of arousal, but the relation with arousal is not simple. Also other factors, such as the need to relieve the pressure on body parts for better blood circulation, cause motility, and spontaneously occurring arousals are part of the normal sleep process. The noise-induced probability of (onset of) motility is the difference between the probability of (onset of) motility during noise events minus the probability in the absence of noise.

Onset of motility and minor arousal found on the basis of EEG recordings are highly correlated. In the United Kingdom sleep disturbance study, Ollerhead et al. (1992) found for their study population that during sleep there is on average an EEG (minor) arousal in 40% of the 30-second intervals with onset of motility. Unfortunately, it is unknown whether this 40% is also valid for noise-induced awakenings. In 12% of the 30-second intervals with an EEG (minor) arousal, motility does not occur. Several field studies (Horne et al., 1994; Fidell et al., 1998, 2000; Flindell, Bullmore and Robertson, 2000; Griefahn et al., 2000; Passchier-Vermeer et al., 2002, 2004) have been conducted regarding noise-induced instantaneous motility. For this effect, relationships have been established with SEL or $L_{Amax}$, for aircraft noise only. In Passchier-Vermeer et al. (2002) relationships between noise-induced increase in motility or noise-induced increase in onset of motility in the 15-second interval with the maximum noise level of an overflight, and $L_{Amax}$ or SEL have been approximated by quadratic functions (see, for instance, Fig. 3.2). It may be noted that the threshold of motility ($L_{Amax}$ = 32 dB(A)) is in the same range as the threshold found by Basner et al. (2004) for EEG awakenings, with a definition that also encompassed transitions to steep stage 1 ($L_{Amax}$ = 35 dB(A)). The probability of motility at 70 dB(A) of about 0.07 is lower than the probability of noise-induced EEG awakening at $L_{Amax}$ = 73 dB(A) of about 0.10. There is no a priori reason to expect the above threshold probabilities to be the same for these two measures of sleep disturbance, but, taking into account that motility is assessed for shorter intervals (15 seconds vs. 90 seconds), the differences in probabilities above threshold appear to be limited.

One of the variables influencing the relationships between noise-induced instantaneous motility and $L_{Amax}$ or SEL, is long-term aircraft noise exposure during sleep. The probability of instantaneous aircraft noise-induced motility is lower when the long-term exposure is higher. This may be partly due to the higher base rate motility in quiet intervals in higher long-term exposure, which is used as a reference for the instantaneous noise-induced motility. Other factors influencing the relationships between instantaneous motility and $L_{Amax}$ or SEL are the point of time in the night, and time since sleep onset. For example, after 7 hours of sleep, noise-induced motility is about 1.3 larger than in the first hour of sleep. Age has only a slight effect on noise-induced motility, with younger and older people showing a lower motility response than persons in the age range of 40–50 years.

### 3.1.7 BEHAVIOURAL AWAKENING IN ADULTS

Passchier-Vermeer (2003a) published a review of nine studies on awakening by noise. It was found that these studies had different definitions of what constituted an "awakening". In this review, however, all awakening data were collected on "behavioural awakening": these are awakenings that were followed by an action (like pressing a button) from the sleeper. The number of awakenings defined in this manner is much smaller than the number of sleep stage changes which lead to EEG patterns similar to wakefulness.

Data were available for rail traffic noise, ambient (probably road) noise, civil aviation noise and military aviation noise.

The rail traffic noise study is very small (only 20 subject nights), but showed no awakenings. The study states that "there is some evidence, be it very limited, that railway noise events, in the range of $SEL_{indoor}$ considered (up to 80 dB(A)), do not increase [the] probability of awakening".

Ambient noise also showed no effect on the probability of awakening, but as it is uncertain exactly what noise is meant, no firm conclusions could be drawn.

Military aircraft noise showed a very strong effect, but this study is of limited applicability since the few subjects (military) lived near the end of the runway.

For civil aviation noise there were sufficient data to derive a dose-effect relation:

$$\text{Percentage of noise-induced awakenings} = -0.564 + 1.909 * 10^{-4} * (SEL_{inside})^2 \qquad [4],$$

where SELinside is the sound exposure level of an aircraft noise event in the bedroom.

This relation is confined to commercial aircraft noise over the intervals $54<SEL<90$ ($37<L_{Amax}<82$) and the number of events per night $1< N< 10$.

With this relation, it is possible to calculate for an individual $L_{night}$ the expected number of noise-induced behavioural awakenings. This requires all single contributions over the year to this $L_{night}$ to be known. Alternatively (if, for instance, a future situation has to be estimated for which no exact data are available) a worst case scenario can be calculated. Fig. 3.1 represents the results of this worst case approach (converted to $L_{night}$, see Chapter 1, section 1.3.4), and so gives the maximum number of awakenings $n_{max}$ that may be expected.

$$n_{max} = 0.3504 * 10^{(L_{night}-35.2)/10} \qquad [5].$$



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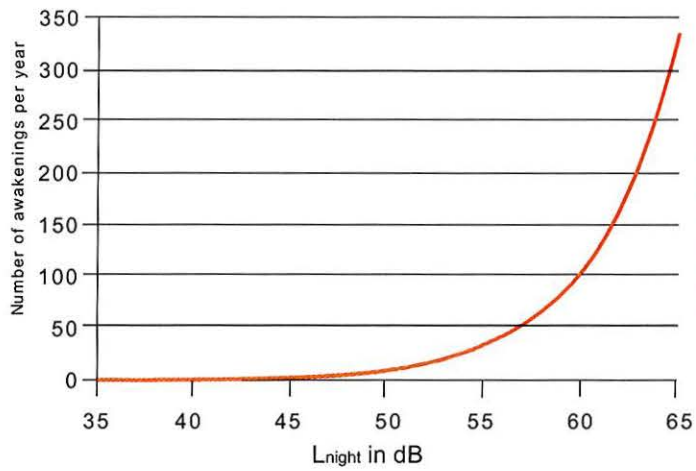


**Fig. 3.1**
**Worst case prediction of noise-induced behavioural awakenings.**
**$L_{night}$, converted from inside relation with [3] on page 10.**

*Source: Miedema, Passchier-Vermeer and Vos, 2003*

It can be demonstrated that the number of awakenings reaches a maximum when the $SEL_{inside}$ value is 58.8 dB(A).

It should be noted that, on average, 600 spontaneous awakenings per person are reported per year. This also explains why so many more awakenings are reported than can be attributed directly to aircraft noise. At 55 $L_{night}$, nearly 100 overflights per night with $SEL_{inside}$ = 58.8, or 1 every 5 minutes are possible. It is, therefore, very likely that an overflight coincides with a spontaneous awakening.

### 3.1.8 DOSE–EFFECT RELATIONS FOR BODY MOVEMENTS DURING SLEEP

In Passchier-Vermeer et al. (2002) motility is registered in 15-second intervals. A distinction is made between two variables:

- the *presence of motility* in the interval (indicated by m) and
- the onset *of motility*, meaning the presence of motility when there was no motility in the preceding interval (indicated by k).

Relations between a noise-induced increase in motility (m) or a noise-induced increase in the onset of motility (k) in the 15-second interval with the maximum sound level of an overflight, and $L_{Amax,inside}$ or $SEL_{inside}$ have been approximated by quadratic functions with the following format:

$$m = b^*(L_{Amax,inside} - a) + c^*(L_{Amax,inside} - a)^2 \qquad [6].$$

The coefficients a, b and c are given in Table 3.1. The value of a is the value below which m or k is zero. Fig. 3.2 shows the relationship between m and $L_{Amax,inside}$ together with the 95% confidence interval. Relations apply to $L_{Amax,inside}$ and $SEL_{inside}$ values of at most 70 and 80 dB(A), respectively.



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Table 3.1.
Coefficients of the quadratic equation (formula [6]) of m and k as a function of $L_{Amax,inside}$ or $SEL_{inside}$ for the 15-second interval in which an indoor maximum sound level of an aircraft noise event occurs. The equations are applicable in the $L_{Amax,inside}$ range from a up to 70 dB(A), or $SEL_{inside}$ range from a up to 80 dB(A). Below a, m and k are zero.

| | (Aircraft) noise-induced increase of probability of motility (m) | (Aircraft) noise-induced increase of probability of onset of motility (k) |
|---|---|---|
| range | $32 < L_{Amax,inside} < 70$ dB(A) (see Fig. 3.2) | $32 < L_{Amax,inside} < 70$ dB(A) |
| a | 32 | 32 |
| b | 0.000633 | 0.000415 |
| c | $3.14x10^{-5}$ | $8.84x10^{-6}$ |
| range | $38 < SEL_{inside} < 80$ dB(A) | $40 < SEL_{inside} < 80$ dB(A) |
| a | 38 | 40 |
| b | 0,000532 | 0.000273 |
| c | $2.68x10^{-5}$ | $3.57x10^{-6}$ |

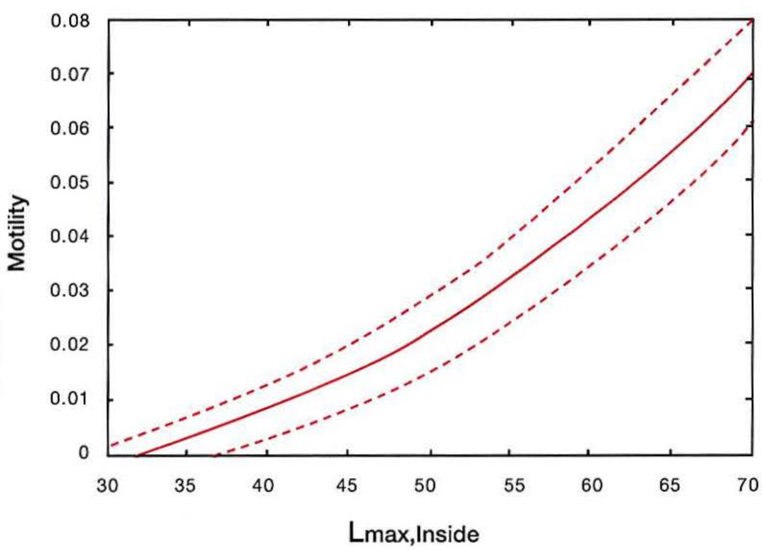


Fig. 3.2
Probability of (aircraft) noise-induced motility (m) at the 15-second interval in which the indoor maximum sound level occurs (solid line) and the 95% confidence interval, as a function of $L_{Amax,inside}$ bedroom

*Source: Miedema, Passchier-Vermeer and Vos, 2003.*

The study report also gives the upper boundaries for motility, based on the relationship between $L_{Amax}$, SEL and $L_{night}$ (Fig. 3.3). This figure is mathematically derived from relation [6] as described in Appendix 2.

This area of study is still under development. Miedema, Passchier-Vermeer and Vos (2003) give a detailed account in their study report of the relation between the study used for the data presented here (Passchier-Vermeer et al., 2002), earlier studies like the much quoted Civil Aviation Authority study (Ollerhead et al., 1992; Ollerhead, 1994) and earlier work done in the United States.



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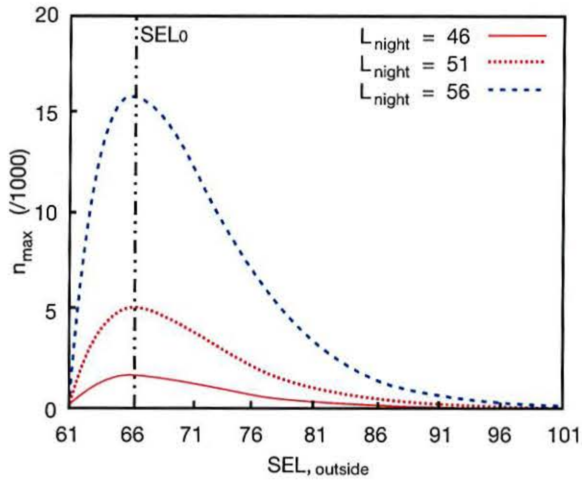


**Fig. 3.3**
**Maximum number of noise-induced motility for three values of $L_{night}$. Converted from inside relation with [3] on page 10**

*Source: Miedema, Passchier-Vermeer and Vos, 2003.*

## 3.1.9 INDIVIDUAL SENSITIVITY

Sensitivity to noise may vary greatly from one individual to another. Primary self-evaluation of sensitivity to noise has been used as a factor to evaluate highly sensitive and non-sensitive groups and to compare their reactions to noise exposure during daytime and night-time (Di Nisi et al., 1990). In this study, self-declared highly sensitive individuals had a higher cardiovascular response rate to noise than non-sensitive people during their waking exposure, while there was no difference in sensitivity to noise between these two groups during their night-time exposure while they were asleep.

The physiological sensitivity to noise depends also on the age of the sleeper. Thus, while EEG modifications and awakening thresholds are, on average, 10 dB(A) higher in children than in adults, their cardiovascular sensitivity to noise is similar, if not higher, than the older group (Muzet and Ehrhart, 1980; see also Appendix 4). Elderly people complain much more than younger adults about environmental noise. However, their spontaneous awakenings occurring during night sleep are also much more numerous. Therefore, it is difficult to conclude if elderly people are more sensitive to noise or if they hear noise because they are often awake during the night. This natural fragmentation of their night sleep tends also to lengthen their return to the sleeping state and this accounts for a significant part of their subjective complaints.

Differences in sensitivity to noise have been found between the sexes. Thus, young men seem to complain more about noise-disturbed sleep than young females (Muzet et al., 1973). However, this difference seems to reverse for populations over 30 years of age and then females (often mothers) appear to be more sensitive to noise than males (Lukas, 1972b).

## 3.1.10 USE OF INSTANTANEOUS EFFECTS IN PREDICTIONS OVER A LONGER TIME PERIOD

It is tempting to use the relations between single exposures and measured effects in long-term predictions. Although this is perhaps possible, a word of caution is appropriate.

In general, the reactions are calculated by looking at a certain time frame around an exposure, usually in the order of a few minutes. The second limitation is that order and follow-up effects are neglected. Time and order effects of identical events on motility have been described by Brink, Wirth and Schierz (2006). Only if the situation that is modelled resembles the one that was used in the single exposure analysis, are no major deviations to be expected. Reactions to noise events are generally not independent from each other. Each event may alter a subject's tendency to awake at the next event, even if no awakening reaction is detected for that particular event. If, for example, each event would additionally increase the probability of awakening at the next event, the total probability of awakening per night would be greater than predicted by mere summation of the single event probabilities. Most likely, this underestimation of probability will occur when events in the real situation follow in close succession, whereas events in the single exposure analysis did not. Such limitations can to some degree be overcome through applying advanced statistical methods such as those put forward by Basner (2006). A third limitation is that an overall increase in the base line could go undetected.

If the situation that is calculated resembles the one that was used in the single exposure analysis, probably no major deviations are to be expected. Care should be taken to extrapolate outside the boundaries given in the number of events or $L_{Amax}$. Calculations for Amsterdam Schiphol Airport show a good agreement between the number of calculated awakenings per year (based on the actual SEL data) and the self-reported number of awakenings. This number is a factor 2 lower than the worst case scenario presented in section 3.1.7 above.

## 3.2 CHRONIC EFFECTS: CHRONIC INCREASE OF MOTILITY

Mean motility – all body movements counted together – during sleep is strongly related to age and is also a function of noise exposure during the sleep period. The relationships between mean motility and $L_{night,inside}$ are shown in Fig. 3.4. Mean motility during sleep is lowest at the age of 45 years, and greater at higher and lower ages. The relation between mean motility, $L_{night,inside}$ and age is:

$$\text{Mean motility} = 0.0587 + 0.000192 * L_{night,inside} - 0.00133 * age + 0.0000148 * age^2 \quad [7].$$

The relation between the increase in mean noise-induced motility, $m_{night}$, and $L_{night,inside}$ is:

$$m_{night} = 0.000192 * L_{night,inside} \quad [8],$$

assuming, as described in Chapter 1, section 1.3.4, that $L_{night,inside} = L_{night}$-21:

$$m_{night} = 0.000192 * L_{night} - 0.004032 \quad [8a].$$

*Source: Miedema, Passchier-Vermeer and Vos, 2003.*



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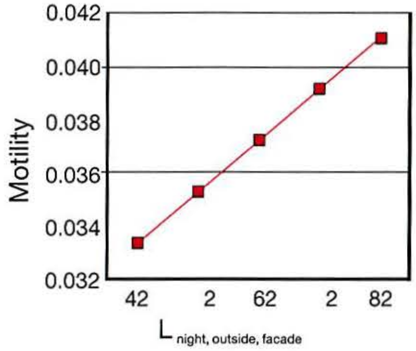



**Fig. 3.4**
**Increase in mean motility (body movements during sleep). Converted from inside relation with [3]**

The increase in $m_{night}$ is 22% over the baseline motility (0.03 on average) if indoor $L_{night, inside}$ increases from 0 (absence of aircraft noise) to 35 dB(A) (living close to a runway). This increase is independent of age, although the absolute level varies.

Other chronic effects like the use of sleeping pills, changes in BP and changes in levels of stress hormones are discussed in the next chapter.

## 3.3 CONCLUSIONS

During sleep the auditory system remains fully functional. Incoming sounds are processed and evaluated and although physiological changes continue to take place, sleep itself is protected because awakening is a relatively rare occurrence. Adaptation to a new noise or to a new sleeping environment (for instance in a sleep laboratory) is rapid, demonstrating this active protection. The physiological reactions do not adapt, as is shown by the heart rate reaction and the increase of average motility with sound level. The autonomous physiological reactions are a normal reaction to these stimuli, but the question is whether prolonged "abuse" of this system leads to adverse consequences for the organism. The next chapter tries to answer that.

# CHAPTER 4

# EFFECTS OF NIGHT-TIME NOISE ON HEALTH AND WELL-BEING

*The sick die here because they can't sleep,*

*For when does sleep come in rented rooms?*
*It costs a lot merely to sleep in this city!*
*That's why everyone's sick: carts clattering*
*Through the winding streets, curses hurled*
*At some herd standing still in the middle of the road,*
*Could rob Claudius or a seal of their sleep!*

*(Juvenal, 1st century AD)*

## 4.1 INTRODUCTION

In Chapters 2 and 3, sufficient evidence was presented to support the hypothesis for the simplified model presented in Chapter 1: sleep disturbance is connected to health impairment, and noise is an important factor that causes sleep disturbance. The full model (Fig. 2.1, Chapter 2) showed why it is difficult to find evidence for a direct relation between noise exposure at night and health outcomes. Noise is but one of the internal and external factors that cause sleep disturbance and feedback loops obscure the view of the cause and effect chain. In this chapter the evidence for the direct relation is presented.

## 4.2 SELF-REPORTED (CHRONIC) SLEEP DISTURBANCES

Self-reported sleep disturbance is investigated by means of a questionnaire containing questions regarding sleep disturbance. Often, sleep disturbance is not the main focus of the questionnaires used in studies of self-reported noise effects. This means that considerable effort is needed to harmonize the different response categories. The relationships for self-reported sleep disturbance are based on analyses of the 15 data sets with more than 12 000 individual observations of exposure–response combinations, from 12 field studies (Miedema, 2003; Miedema, Passchier-Vermeer and Vos, 2003).

The curves are based on data in the $L_{night}$ (outside, most exposed facade) range 45–65 dB(A). The polynomial functions are close approximations of the curves in this range and their extrapolations to lower exposure (40–45 dB(A)) and higher exposure (65–70 dB(A)). The formulae of these polynomial approximations are as follows (SD = sleep disturbance; H = high; L = low):

for road traffic:

$$\%HSD = 20.8 - 1.05*L_{night} + 0.01486*(L_{night})^2 \quad [9]$$

$$\%SD = 13.8 - 0.85*L_{night} + 0.01670*(L_{night})^2 \quad [10]$$

$$\%LSD = -8.4 + 0.16*L_{night} + 0.01081*(L_{night})^2 \quad [11]$$

for **aircraft:**

$$\%HSD = 18.147 - 0.956{*}L_{night} + 0.01482{*}(L_{night})^2 \quad [12]$$

$$\%SD = 13.714 - 0.807{*}L_{night} + 0.01555{*}(L_{night})^2 \quad [13]$$

$$\%LSD = 4.465 - 0.411{*}L_{night} + 0.01395{*}(L_{night})^2 \quad [14]$$

and for **railways:**

$$\%HSD = 11.3 - 0.55{*}L_{night} + 0.00759{*}(L_{night})^2 \quad [15]$$

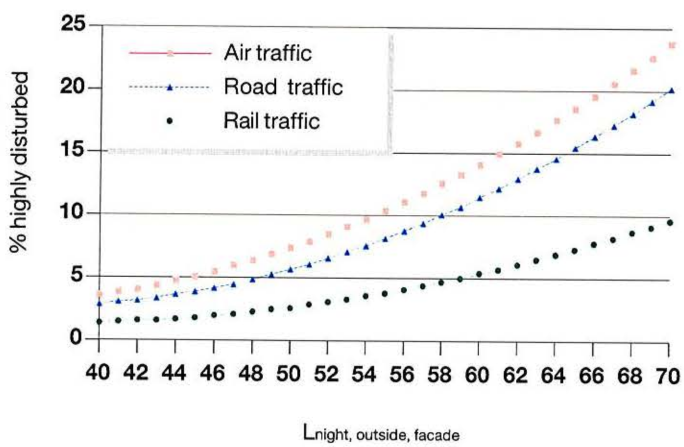
$$\%SD = 12.5 - 0.66{*}L_{night} + 0.01121{*}(L_{night})^2 \quad [16]$$

$$\%LSD = 4.7 - 0.31{*}L_{night} + 0.01125{*}(L_{night})^2 \quad [17].$$

The above relations represent the current best estimates of the influences of $L_{night}$ on self-reported sleep disturbance for road traffic noise and for railway noise, when no other factors are taken into account. Fig. 4.1 illustrates the relations [9] [12] and [15] for persons highly disturbed by road, aircraft and rail noise.

**Fig. 4.1**
**High sleep disturbance by noise at night**

*Source: European Commission, 2004.*




With regard to the relations for aircraft noise it should be noted that the variance in the responses is large compared to the variance found for rail and road traffic. This means that the uncertainty regarding the responses for night-time aircraft noise is large, and such responses can be considered as indicative only. Miedema (2003) suggests the following causes.

- The time pattern of noise exposures around different airports varies considerably due to specific night-time regulations.
- The sleep disturbance questions for aircraft noise show a large variation.
- The most recent studies show the highest self-reported sleep disturbance at the same $L_{night}$ level. This suggests a time trend.

For industrial noise there is an almost complete lack of information, although there are some indications (Vos, 2003) that impulse noise may cause considerable disturbance at night.

## 4.3 COMPLAINTS

According to the Health Council of the Netherlands (2004), the submission of a complaint about noise is symptomatic of reduced well-being.

Complaints about noise are widespread, and night noise seems to cause more complaints than daytime noise at the same level. Hume, Morley and Thomas (2003) found that around Manchester Airport complaints per 1000 aircraft traffic movements rose from an average of 10 in daytime hours to up to 80 in the night. When linking part of the complaints to measured noise levels, they found an increase from an average of 1 complaint at 70 PNLdB (circa 58 $L_{Amax}$) to 2 at 114 PNLdB (circa 102 $L_{Amax}$).

Due to differences in complaint cultures and registration practices, it is difficult to make comparisons between complaint registrations. Around Amsterdam Schiphol Airport a relation between complaints and $L_{Aeq}$ was found (Ministerie Verkeer en Waterstaat, 2005). The threshold for complaints is around 45 $L_{den}$, and increases to 7% of the population at 72 $L_{den}$. Night-time complaints follow the same pattern, and the threshold for night complaints is 35 $L_{night}$. In Fig. 4.2 the mean percentage shows a definite relationship with $L_{night}$. The 95 percentile indicates that the threshold is 35 $L_{night}$.

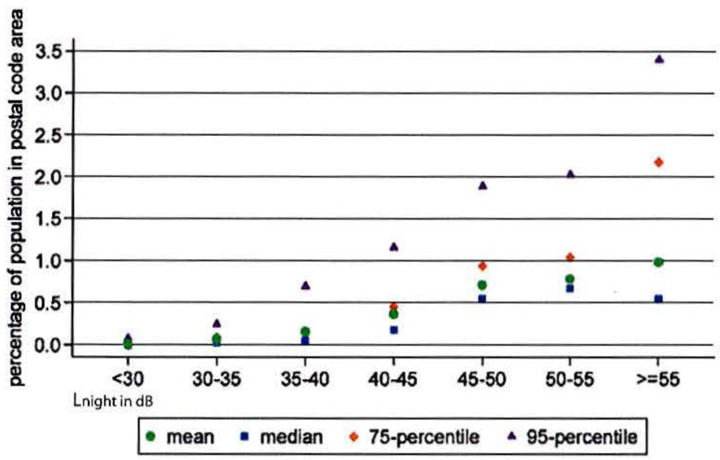



**Fig. 4.2 Dose-effect relation for persons having complained at least once during a year between 1994 and 2004**

*Source: Ministerie Verkeer en Waterstaat (2005).*

## 4.4 NEIGHBOURHOOD NOISE AND NOISE FROM NEIGHBOURS

Inventory studies in the Netherlands indicate that sleep disturbance attributable to the most annoying forms of neighbourhood noise and noise from neighbours (contact noise and human noises in the environment) is on a similar scale to disturbance attributable to the most annoying sources of road traffic noise (mopeds and passenger cars). It is reasonable to assume that chronic sleep disturbance is, in the long term, liable to have consequences for health and well-being. The sound pressure level and other noise characteristics are liable to determine the nature of the influence to some extent, but certain other factors play a more prominent role than is the case with traffic noise. These factors include appreciation of the noise and of the party responsible for the noise, as well as the hearer's personal circumstances. However, scientific understanding of the relative importance of and interaction between acoustic and non-acoustic factors is not sufficient for the committee to draw any definitive conclusions regarding the relationship between, on the one hand, exposure to night-time neighbourhood noise and noise from neighbours and, on the other, health and well-being.

Leidelmeijer and Marsman (1997) carried out an interview-based study of 1242 households in the Netherlands, in which subjects were asked about daytime and night-time noise from neighbours and any associated annoyance. A distinction was made on the basis of the part of the house in which the noises were audible and any associated annoyance was experienced. Subjects proved least tolerant of noise from their neighbours that was audible in the master bedroom. The researchers distinguished five types of noise, which are listed below (Table 4.1), along with the percentage of subjects who indicated hearing the relevant type of noise from a neighbouring dwelling at night in the master bedroom.

**Table 4.1**
**Daytime and night-time noise from neighbours**

| Type of noise | % subjects hearing noises at night in the bedroom |
|---|---|
| Contact noise | 22% |
| Noise from sanitary fittings, central heating, etc. | 19% |
| Noise from radio, TV and hi-fi | 12% |
| Do-it-yourself noises | 8% |
| Pets | 6% |

*Source: Leidelmeijer and Marsman, 1997.*

Where each of the five investigated types of noise was concerned, roughly 10–15% of subjects indicated that they felt it was unacceptable for the noise to be audible during the day. Overall, nearly 30% of subjects said that sanitary fittings should not be audible at night, while approximately 50% felt each of the other four types of noise was unacceptable at night.

In 1993, Kranendonk, Gerretsen and van Luxemburg produced a synthesis of the research conducted up to that point in time into the annoyance associated with noise from neighbours. Subsequently, in 1998, van Dongen et al. published a report on the relationship between noise from neighbouring dwellings and the airborne and contact noise attenuating indices $I_{lu}$, $I_{lu;k}$, and $I_{co}$, drawing on data from a questionnaire-based survey of the residents of 600 dwellings, whose acoustic quality was determined in 202 cases. The results of the two studies are reasonably consistent. Both found that the chief causes of annoyance were loud radios, hi-fis and TVs, audible and sometimes intelligible voices, the slamming of doors and footsteps on floors and staircases. In both cases, it proved that, when Ilu had a value of 0 (the minimum requirement for new homes), 10% of subjects reported high annoyance and 15% reported annoyance caused by noise from neighbouring dwellings. These figures are not specific to night-time noise, but apply to annoyance over a 24-hour period.

On the basis of the findings outlined above, the committee concludes that the standard of inter-dwelling sound attenuation presently required does not provide sufficient protection to prevent annoyance caused by noise from neighbours. Since people are less tolerant of the noise their neighbours make at night-time than of their neighbours' evening or daytime noise, it may be assumed that much of the annoyance associated with noise from neighbours relates to the influence of such noise on sleep.

# 4.5 CARDIOVASCULAR EFFECTS OF NOISE – FINDINGS FROM EPIDEMIOLOGICAL STUDIES

## 4.5.1 INTRODUCTION

It is a common experience that noise is unpleasant and affects the quality of life. It disturbs and interferes with activities of the individual including concentration, communication, relaxation and sleep (WHO Regional Office for Europe, 2000; Schwela, 2000). Besides the psychosocial effects of community noise, there is concern about the impact of noise on public health, particularly regarding cardiovascular outcomes (Suter, 1992; Passchier-Vermeer and Passchier, 2000; Stansfeld, Haines and Brown, 2000). Non-auditory health effects of noise have been studied in humans for a couple of decades using laboratory and empirical methods. Biological reaction models have been derived, which are based on the general stress concept (Selye, 1956; Henry and Stephens, 1977; Ising et al., 1980; Lercher, 1996). Amongst other non-auditory health end points, short-term changes in circulation including BP, heart rate, cardiac output and vasoconstriction, as well as stress hormones (epinephrine, norepinephrine and corticosteroids) have been studied in experimental settings for many years (Berglund and Lindvall, 1995; Babisch, 2003). Various studies have shown that classical biological risk factors are higher in subjects who were exposed to high levels of traffic noise (Arguelles et al., 1970; Eiff et al., 1974; Verdun di Cantogno et al., 1976; Algers, Ekesbo and Strömberg, 1978; Knipschild and Sallé, 1979; Manninen and Aro, 1979; Eiff et al., 1981a; Rai et al., 1981; Marth et al., 1988; Babisch and Gallacher, 1990; Babisch et al., 1990; Lercher and Kofler, 1993; Schulte and Otten, 1993; Dugué Leppänen and Gräsbeck, 1994; Yoshida et al., 1997; Goto and Kaneko, 2002). Although controls for other risk factors were not consistent in all these studies, the hypothesis emerged that persistent noise stress increases the risk of cardiovascular disorders including high BP (hypertension) and IHD.

- Sound/noise is a psychosocial stressor that activates the sympathetic and endocrine system.
- Acute noise effects do not only occur at high sound levels in occupational settings, but also at relatively low environmental sound levels when, more importantly, intended activities such as concentration, relaxation or sleep are disturbed.

The following questions need to be answered.

- Do these changes observed in the laboratory habituate or persist under chronic noise exposure?
- If they habituate, what are the physiological costs? If they persist, what are the long-term health effects?

The answers to these questions come from epidemiological noise research. Large-scale epidemiological studies have been carried out for a long time (Babisch, 2000). The studies suggest that transportation noise is associated with adverse cardiovascular effects, in particular IHD. The epidemiological evidence is constantly increasing (Babisch, 2002, 2004a). The biological plausibility of the association derives from the numerous noise experiments that have been carried out in the laboratory. There is no longer any need to prove the noise hypothesis as such. Decision-making and risk management, however, rely on a quantitative risk assessment which requires an established dose–response relationship. Since many of the stress indicators and risk factors that have been investigated in relation to

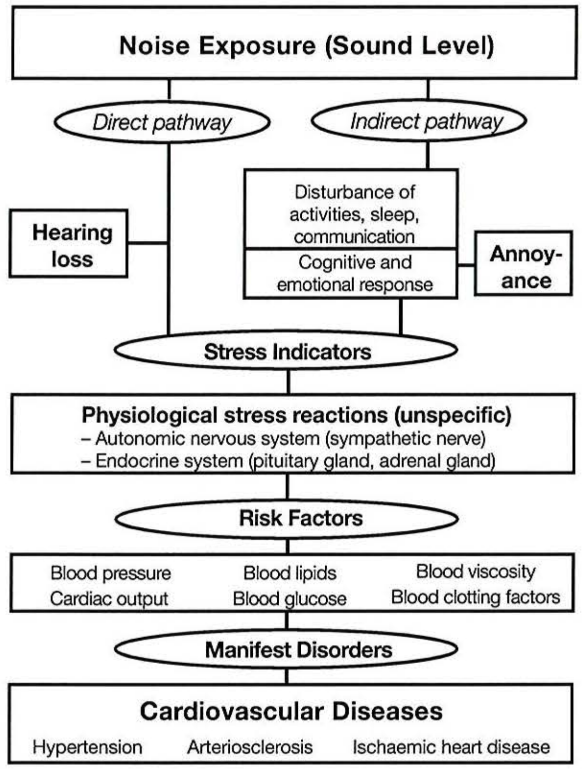



**Fig. 4.3 Noise effects reaction scheme**

*Source: Babisch, 2002.*

noise are known to be classical cardiovascular risk factors, the hypothesis has emerged that chronic noise exposure increases the risk of hypertension, arteriosclerosis and IHD. Its relevance for public health comes from the high prevalence of cardiovascular diseases in developed and industrialized countries. It is unclear as to what extent chronically repeated noise-induced sleep disturbance contributes to the development of somatic health disorders. Only a few epidemiological studies address this particular issue. Epidemiological noise research has seldom distinguished between day and night exposures, or between the exposure of the living room and the bedroom. However, some deduction can be made from daytime to night-time exposure.

## 4.5.2 NOISE AND STRESS-REACTION MODEL

The auditory system is continuously analysing acoustic information, which is filtered and interpreted by different cortical and subcortical brain structures. The limbic system, including the hippocampus and the amygdala, plays an important role in the emotional processing pathways (Spreng, 2000). It has a close connection to the hypothalamus that controls the autonomic nervous system and the hormonal balance of the body. Laboratory studies found changes in blood flow, BP and heart rate in reaction to noise stimuli as well as increases in the release of stress hormones including the catecholamines adrenaline and noradrenaline, and the corticosteroid cortisol (Berglund and Lindvall, 1995; Maschke, Rupp and Hecht, 2000; Babisch, 2003). Such changes also occur during sleep without the involvement of cortical structures. The amygdala has the capacity to learn due to its plasticity, particularly with respect to the meaning of sound stimuli (for example, danger of an approaching lorry) (Spreng, 2000, 2004). Acoustic stimulation may act as an unspecific stressor that arouses the autonomous nervous system and the endocrine system. The generalized psychophysiological concept given by Henry and Stephens can be applied directly to noise-induced stress reaction (Henry, 1992). The stress mechanism as such is genetically determined but it may be modified by experience and environmental factors. Its biological function is to prepare the organism to cope with a demanding stressor. The arousal of the sympathetic and endocrine system is associated with changes in physiological functions and the metabolism of the organism, including BP, cardiac output, blood lipids (cholesterol, triglycerides, free fatty acids, phosphatides), carbohydrates (glucose), electrolytes (magnesium, calcium), blood clotting factors (thrombocyte aggregation, blood viscosity, leukocyte count) and others (Friedman and Rosenman, 1975; Cohen, Kessler and Underwood Gordon, 1995; Lundberg, 1999). In the long term, functional changes and dysregulation may occur, thus increasing the risk of manifest diseases.

Fig. 4.3 shows the principal reaction schema used in epidemiological noise research for hypothesis testing (Babisch, 2002). It simplifies the cause–effect chain, that is: sound – annoyance (noise) – physiological arousal (stress indicators) – (biological) risk factors – disease – and mortality (the latter is not explicitly considered in the graph). The mechanism works "directly" through synaptic nervous interactions and "indirectly" through the emotional and the cognitive perception of the sound. It should be noted that the "direct" pathway is relevant even at low sound levels particularly during sleep, when the organism is at its nadir of arousal. The objective noise exposure (sound level) and the subjective noise "exposure" (annoyance) may serve independently as exposure variables in the statistical analyses of the relationship between noise and health end points.

Principally, the effects of environmental noise cannot directly be extrapolated from results of occupational noise studies. The two noise environments cannot simply be merged into one sound energy-related dose–response model (for example, a simple 24-hour average noise level measured with a dose-meter). Noise effects are not only dependent on the sound intensity but also on the frequency spectrum, the time pattern of the sound and the individuals' activities which are disturbed. Therefore, epidemiological studies carried out under real-life conditions can provide the basis for a quantitative risk assessment provided that there is adequate control over confounding and exposure variables. Other noise sources might act as confounders and/or effect modifiers on the association of interest. The effects of road traffic noise (at home) were shown to be stronger in subjects who were also exposed to high noise levels at work (Babisch et al., 1990).

### 4.5.3 PREVIOUS REVIEWS ON ENVIRONMENTAL NOISE AND CARDIOVASCULAR RISK

Causality in epidemiology can never be completely proven (Schlesselman, 1987; Christoffel and Teret, 1991; Weed, 2000). It is a gradual term for which evidence is increasing with the increasing number of facts. However, the magnitude of effect, the presence of a dose–response relationship and consistency with other studies in different populations and with different methodology and biological plausibility are commonly accepted arguments for a causal relationship (Bradford Hill, 1965; Evans, 1976; Morabia, 1991; Weed and Hursting, 1998). Classical, systematic and quantitative reviews have been published in the past, summarizing the results of studies that have been carried out up to the end of the last century, and assessing the evidence of the relationship between community noise and cardiovascular disease outcomes (Health Council of the Netherlands, 1994, 1999, 2004; Berglund and Lindvall, 1995; IEH, 1997; Morrell, Taylor and Lyle, 1997; Porter, Flindell and Berry, 1998; Babisch, 2000; Passchier-Vermeer and Passchier, 2000), including a classical review and synthesis report by Babisch (2000) and a systematic review (meta-analysis) by van Kempen et al. (2002).

In a meta-analysis it was concluded that the risk of hypertension due to aircraft noise was 1.26 per increase of 5 dB(A) (95% CI: 1.14–1.39, $L_{day}$ = 55–72 dB(A)) (van Kempen et al., 2002). But, only one study (Knipschild, 1977a) was considered in the meta-analysis. With respect to road traffic noise and hypertension a pooled estimate of 0.95 per 5 dB(A) (95% CI: 0.84–1.08, $L_{day}$ = <55–80 dB(A)) was calculated (van Kempen et al., 2002). Two cross-sectional studies (Knipschild and Sallé, 1979; Knipschild, Meijer and Sallé, 1984) were considered in this calculation. The highest degree of evidence was for the association between community noise and IHD. Across the studies there was not much indication of an increased risk for subjects who lived in areas with a daytime average sound pressure level of less than 60 dB(A). For higher noise categories, however, higher risks were relatively consistently found amongst the studies (Babisch, 2004a). Statistical significance was rarely achieved.

Some studies permit reflections on dose–response relationships. These mostly prospective studies suggest an increase in risk for outdoor noise levels above 65–70 dB(A) during the daytime, the relative risks ranging from 1.1 to 1.5. Noise effects were larger when mediating factors like years in residence, room orientation and window-opening habits were considered in the analyses. In a meta-analysis it was concluded that the risk of IHD increased by 1.09 per 5 dB(A) of the road traffic noise level (95% CI: 1.05–1.13, $L_{day}$ = 51–70 dB(A)) (van Kempen et al., 2002), when two cross-sectional studies (Babisch et al., 1993a) were considered. However, the pooled estimate of two prospective studies (Babisch et al., 1999) was calculated to be 0.97 per 5 dB(A) (95% CI: 0.90–1.04, $L_{day}$ = 51–70 dB(A)) (van Kempen et al., 2002). When the diagnosis of IHD was limited to myocardial infarction, three studies (Babisch et al., 1999, 1994) were considered in this meta-analysis. Then the linear effect estimate was 1.03 per 5 dB(A) increase in road traffic noise level (95% CI: 0.99–1.09, $L_{day}$ = 51–80 dB(A)). New studies have appeared in the meantime which are included in the present updated review (Matsui et al., 2001; Bluhm, Nordling and Berglind, 2001; Evans et al., 2001; Rosenlund et al., 2001; Belojevic and Saric-Tanaskovic, 2002; Goto and Kaneko, 2002; Lercher et al., 2002; Maschke, 2003; Franssen et al., 2004; Matsui et al., 2004; Niemann and Maschke, 2004; Babisch et al., 2005). Others are on their way or have not yet been finalized and published, for instance the pan-European HYENA project (Jarup et al., 2003).

## 4.5.4 UPDATED REVIEW OF EPIDEMIOLOGICAL STUDIES

Sixty epidemiological studies were recognized as having either objectively or subjectively assessed the relationship between transportation noise and cardiovascular end points. The identification of studies was based on the author's expert knowledge of the topic and respective literature. Details are given in the major report (Babisch, 2006). Information particularly on night-time exposure ($L_{night}$: 22.00–06.00 or 23.00–07.00) was seldom available. Newer studies used non-weighted or weighted averages of the 24-hour exposure ($L_{eq}$, $L_{dn}$, $L_{den}$). Some aircraft noise studies used national calculation methods (for example, Dutch Kosten Units). For comparisons of study results and the pooling of data (meta-analysis), sound levels were converted on the basis of best guess approximations to $L_{day}$ (Matschat and Müller, 1984; Passchier-Vermeer, 1993; Bite and Bite, 2004; Franssen et al., 2004). It should be noted in this context that doubling/halving of road traffic volume results in a 3 dB(A) higher/lower average sound pressure level. Not all studies allowed dose–response reflections because some of them considered very broad exposure categories. Besides objective noise measurements, subjective measurements of exposure have been used in some epidemiological noise studies, which is in accordance with the noise–stress model. Type of road (for example, busy street, side street, etc.), disturbances and annoyance were rated by the study subjects from given scales.

### 4.5.5 MEAN BP

Table A2 of the major report (Babisch, 2006) lists the major findings of epidemiological traffic noise studies in which mean BP was considered as the outcome. It indicates mean systolic and diastolic BP differences as obtained from extreme group comparisons of noise exposure. The effects in children and in adults are discussed separately. The findings in children are difficult to interpret with regard to possible health risks in their later life. The effect may be of a temporary nature and may not be relevant to permanent health damage. There is evidence during childhood (Gillman et al., 1992), adolescence (Yong et al., 1993) and adulthood (Tate et al., 1995) that the BP level at an early age is an important predictor of the BP level at a later age. Studies over the full age range are missing (tracking). Growth and body weight are important factors in BP development. The impact of body size was not adequately considered in some of the studies. A crude hint regarding reversible effects on BP came from one study (Morrell et al., 2000). Results of the Munich intervention study on the effects of a reduction of aircraft noise have only been reported regarding cognitive performance but not with respect to change of BP (Hygge, Evans and Bullinger, 2002). It was concluded from the available data on the length of exposure that children do not seem to adapt to high levels of road traffic noise but to some extent to aircraft noise (Passchier-Vermeer, 2000; Bistrup et al., 2001). However, the database appears to be too poor to draw final conclusions. Aircraft noise studies focused on exposure at school, while road traffic noise studies mostly considered noise exposure at home. The conclusions given by Evans and Lepore (1993) seem still to hold true:

> "We know essentially nothing about the long-term consequences of early noise exposure on developing cardiovascular systems. The degree of blood pressure elevations is small. The clinical significance of such changes in childhood blood pressure is difficult to determine. The ranges of blood pressure among noise-exposed children are within the normal levels and do not suggest hypertension. The extent of BP elevations found from chronic exposure are probably not significant for children during their youth, but could portend elevations later in life that might be health damaging."

Regarding mean BP, no consistent findings in the relationship between traffic noise level and mean systolic or diastolic BP can be seen in adults across the studies. In longitudinal studies, problems arose from migration of subjects, which had a considerable impact on sample size. The latter problem also applies to cross-sectional studies, in general. Sensitive subjects may tend to move out of the polluted areas, which dilutes the effect of interest. Medication due to high BP may affect the BP readings. However, the exclusion of subjects with hypertension or hypertension treatment dilutes the true effect on BP differences, if the hypothesis (noise causes high BP) is true. In principle, hypotension – a fall in BP – can also be a stress reaction. All this makes it more reasonable to look at manifest hypertension (defined by a cut-off criterion) as a clinical outcome rather than at mean BP readings (Ising, 1983; Winkleby, Ragland and Syme, 1988). To date, there is no evidence from epidemiological data that community noise increases mean BP readings in the adult population. However, this does not discard the noise hypothesis as such. Studies suffered from insufficient power, narrow exposure range or other difficulties in the study design.

## 4.5.6 HYPERTENSION

Table A3 of the major report (Babisch, 2006) gives the results of epidemiological traffic noise studies on the relationship between community noise level and the prevalence or incidence of hypertension. Hypertension in these studies was either defined by WHO criteria (WHO-ISH Guidelines Subcommittee, 1999), similar criteria based on measurements of systolic and diastolic BP, from information which was obtained from a clinical interview, or a social survey questionnaire about hypertension diagnosed by a doctor. Most studies refer to road traffic noise. However, in recent years some new aircraft noise studies entered the database. The subjects studied were the adult male and female population, sometimes restricted to certain age ranges. With regard to the association between community noise and hypertension, the picture is heterogeneous. With respect to aircraft noise and hypertension, studies consistently show higher risks in higher exposed areas. The evidence has improved since a previous review (Babisch, 2000). The relative risks found in four significantly positive studies range between 1.4 and 2.1 for subjects who live in high exposed areas, with approximate daytime average sound pressure level in the range of 60–70 dB(A) or more. Swedish studies found a relative risk of 1.6 at even lower levels >55 dB(A). With respect to road traffic noise, the picture remains unclear. New studies, more than older studies, tend to suggest a higher risk of hypertension in subjects exposed to high levels of road traffic noise, showing relative risks between 1.5 and 3.0. However, the earlier studies cannot be neglected in the overall judgement process. Across all studies no consistent pattern of the relationship between community noise and prevalence of hypertension can be seen. Dose–response relationships were considered in new studies. Subjective ratings of noise or disturbances due to traffic noise seem to consistently show a positive association with prevalence of hypertension. The relative risks found here range from 0.8 to 2.3. These studies, however, are of lower validity due to principal methodological issues regarding over-reporting (Babisch et al., 2003).

## 4.5.7 IHD

Table A5 of the major report (Babisch, 2006) gives the results of cross-sectional epidemiological traffic noise studies on the relationship between noise level and prevalence of IHD. Table A6 of the major report gives the results of case-control and cohort studies on the association between noise level and incidence of IHD. In cross-sectional studies, IHD prevalence was assessed by clinical symptoms of angina pectoris, myocardial infarction, ECG abnormalities as defined by WHO criteria (Rose and Blackburn, 1968), or from self-reported questionnaires regarding doctor-diagnosed heart attack. In longitudinal studies, IHD incidence was assessed by clinical myocardial infarction as obtained from hospital records, ECG measurements or clinical interviews. The majority of studies refer to road traffic noise. With regard to IHD, the evidence of an association between community noise and IHD risk has increased since a previous review (Babisch, 2000). There is not much indication of a higher IHD risk for subjects who live in areas with a daytime average sound pressure level of less than 60 dB(A) across the studies. For higher noise categories, a higher IHD risk was relatively consistently found amongst the studies. Statistical significance was rarely achieved. Some studies permit reflections on dose–response relationships. These mostly prospective studies suggest an increase in IHD risk at noise levels above 65–70 dB(A), the relative risks ranging from 1.1 to 1.5 when the higher exposure categories were grouped together. Noise effects were larger when mediating factors like residence time, room orientation and window-opening habits were considered in the analyses. This accounts for an induction period (Rose, 2005) and improves exposure assessment. The results appear as consistent when subjective responses of disturbance and annoyance are considered, showing relative risks ranging from 0.8 to 2.7 in highly annoyed/disturbed/affected subjects. However, these findings may be of lower validity due to methodological issues.

### 4.5.8 MEDICATION AND DRUG CONSUMPTION

Table A8 of the major report (Babisch, 2006) gives the results of studies on the relationship between drug consumption and community noise. Medication was primarily investigated with respect to aircraft noise. A significant prevalence ratio for medication with cardiovascular drugs of 1.4 was found in the sample of Amsterdam Schiphol Airport (Knipschild, 1977a). The results of the "drug survey", where the annual data of the pharmacies regarding the purchase of cardiovascular drugs were analysed (repeated cross-sectional survey), supported this finding. An increase in drug purchase over time in the exposed areas and not in the less exposed was found. This refers to the purchase of cardiovascular and antihypertensive drugs, as well as the purchase of hypnotics, sedatives and antacids (Knipschild and Oudshoorn, 1977). Furthermore a dependency with changes in night flight regulations was found (decrease after reduction of night flights). A large recent study around Amsterdam Schiphol Airport found only a slightly higher risk of self-reported medication with cardiovascular drugs, including antihypertensive drugs (relative risk 1.2), in subjects exposed to aircraft noise where the noise level $L_{den}$ exceeded 50 dB(A) (Franssen et al., 2004). Dose–response relationships across noise levels ($L_{den}$ = <50–65 dB(A)) with respect to prescribed and non-prescribed sedatives/sleeping pills were found (relative risk 1.5 and 2.0, respectively) in the highest noise category of $L_{den}$ = 61–65 dB(A). The preliminary results of an ongoing aircraft noise study from Sweden carried out around Stockholm's airport are in line with the Dutch studies (Bluhm et al., 2004). A significant relative risk of 1.6 for the use of antihypertensive drugs was found in male subjects, where the noise level according to the Swedish calculation standard exceeded FBM = 55 dB(A). The road traffic noise studies, where medication/purchase of drugs was investigated also tend to show a higher use in higher exposed subjects (Eiff and Neus, 1980; Schulze et al., 1983; Lercher, 1992). The relative risk for cardiovascular drugs was 1.3 in the Bonn study and 5.0 in the Erfurt study. The results for other drugs including sleeping pills, sedatives, tranquillizers and hypnotics ranged between 1.2 and 3.8 in these studies. All in all, the studies on the relationship between the use of medication or purchase of drugs and community noise support the general hypothesis of an increase in sleep disturbance and cardiovascular risk in noise-exposed subjects.

### 4.5.9 EVALUATION OF STUDIES

This section refers only to studies where the prevalence or the incidence of manifest cardiovascular diseases was considered as a potential health outcome of chronic exposure to environmental noise. The focus here is on a quantitative risk assessment with respect to manifest diseases. Furthermore, studies on the effects of low-altitude jet-fighter noise are also excluded, because this type of noise includes other dimensions of stress (for instance, fear). Thirty-seven studies have assessed the prevalence or incidence of manifest diseases, including hypertension and IHD (angina pectoris, myocardial infarction, ECG abnormalities).

#### *4.5.9.1 Criteria*

Epidemiological reasoning is largely based on the magnitude of effect estimates, dose–response relationships, consistency of findings, biological plausibility of the effects and exclusion of possible bias. Internal (the role of chance) and external validity (absence of bias and confounding) are important issues in the evaluation of studies (Bradford Hill, 1965). Analytic studies (for example, cohort or case-control studies) are usually considered as having a higher validity and credibility than descriptive studies (for example, cross-sectional or ecological studies) (Hennekens and Buring, 1987), although many of the reservations against cross-sectional studies seem to be of minor importance when considering noise. For example, it does not appear to be very likely that diseased subjects tend to move differentially more often into exposed areas. Rather the opposite may be true, if noise stress is recognized as a potential cause of the individual's health problem. Thus, a cross-sectional study design may act conservatively on the results. The presence of a dose–response relationship is not a necessary criterion of causality. Non-linear relationships, including "u-" or "j-" shaped, saturation and threshold effects may reflect true associations (Calabrese and Baldwin, 2003; Rockhill, 2005). With respect to the derivation of guideline values in public health policy, the assessment of a dose–response relationship enables a quantitative risk assessment on the basis of continuous or semi-continuous (for instance 5 dB(A) categories) exposure data. Dichotomous exposure data, on the other hand, that refer to a cut-off criterion which splits the entire exposure range into two halves, can be used to evaluate the hypothesis of an association (qualitative interpretation), but not a quantitative assessment. The objective or subjective assessment of exposure and/or health outcomes is an important issue when judging the validity of a study (Malmström, Sundquist and Johansson, 1999; Cartwright and Flindell, 2000; Hatfield et al., 2001). The objective prevalence of hypertension was found to be higher in a population sample than the subjective prevalence of hypertension (Schulte and Otten, 1993). In a telephone survey more than half of the hypertensives classified themselves as normotensive (sensitivity 40% for men and 46% for women) (Bowlin et al., 1993). In a representative health survey, the validity of the self-reported assessment of morbidity (subjective morbidity) was found to be "low" with respect to hypercholesterolaemia, "intermediate" with respect to angina pectoris, hypertension and stroke and "high" with respect to myocardial infarction (Bormann et al., 1990). Myocardial infarction is a very definite and severe health outcome which subjects would clearly know about if they had experienced it. Its assessment by questionnaire tends to be more credible than that regarding hypertension. Test–retest reliability was found to be good with respect to "harder" outcomes, including high BP and heart attack (Lundberg and Manderbacka, 1996; Lipworth et al., 2001). Over-reporting, on the other hand, may be a source of potential bias, particularly when both exposure and outcome are assessed on a subjective basis (Winkleby, Ragland and Syme, 1988; Babisch et al., 2003). The subjects may be more prone to blame their environment for their health problems, or may even tend to exaggerate adverse effects or exposure in order to influence noise policy. Therefore, a higher credibility and ranking was given to studies where exposure and outcome were assessed objectively (for example sound level versus subjective ratings, and measurement of BP or a clinical interview versus self-reported hypertension in a self-administered questionnaire). This means that the sound level must have been measured or calculated on the basis of the traffic counts, and clinical interviews or measurements must have been carried out by medically trained personnel (no self-administered questionnaire data) to give a study a high ranking. Studies which have been adequately controlled (for instance stratification, model adjustment (regression), matching) for a reasonable set of confounding variables in the statistical analyses, besides age and sex, were given a high ranking.

#### *4.5.9.2 Assessment*

The evaluation concerning the epidemiological studies was made with respect to the identification of good quality studies that can be feasibly considered for the derivation of guideline values. These studies can either be used for a statistical meta-analysis, for a combined interpretation (synthesis) or for singular interpretations. All the studies were evaluated with respect to the following criteria for inclusion or exclusion in the synthesis process. Necessary criteria were: (1) peer-reviewed in the international literature; (2) reasonable control of possible confounding; (3) objective assessment of exposure; (4) objective assessment of outcome; (5) type of study; and (6) dose–response assessment. All six criteria were fulfilled by the two prospective cohort studies carried out in Caerphilly and Speedwell (Babisch et al., 1999; Babisch, Ising and Gallacher, 2003), the two prospective case-control studies carried out in the western part of Berlin ("Berlin I" and "Berlin II") (Babisch et al., 1992, 1994), and the new prospective case-control study carried out in the whole of Berlin ("NaRoMI" = "Berlin III") (Babisch, 2004b; Babisch et al., 2005). The studies refer to road traffic noise and the incidence of myocardial infarction. They were also the only ones considered in an earlier meta-analysis on this issue (van Kempen et al., 2002), with the exception of the "NaRoMI" study, which was not available at that time. All these studies are observational analytic studies (Hennekens and Buring, 1987). If descriptive studies on individuals – namely cross-sectional studies – are allowed, another two studies from Caerphilly and Speedwell on the association between road traffic noise and the prevalence of IHD, myocardial infarction and angina pectoris can be taken into account (Babisch et al., 1988, 1993a, 1993b). These studies were also considered in the meta-analysis by van Kempen et al. (2002). However, the results of the Berlin study on the prevalence of myocardial infarction (Babisch et al., 1994) – which was also considered in that meta-analysis – are not considered here, because the outcome was assessed subjectively with a self-administered questionnaire (an exclusion criterion). All the studies suggest an increase in IHD, in particular myocardial infarction. These studies are used for a new meta-analysis (section 4.5.10).

Regarding aircraft noise, the cross-sectional Okinawa study (Matsui et al., 2001; Matsui et al., 2004) on the association between aircraft noise and hypertension fulfils the inclusion criteria. When studies are included that did not assess dose–response relationships but only compared dichotomous categories of exposure in the analyses, two more studies appear on the list. The studies were carried out in the vicinity of Amsterdam Schiphol Airport. They suggest a higher risk of cardiovascular diseases in general (Knipschild, 1977b), and – specifically – for hypertension and IHD (angina pectoris, ECG abnormalities, heart trouble) (Knipschild, 1977a) in subjects from areas exposed to high aircraft noise. These studies were considered in the meta-analysis by van Kempen et al. (2002). However, they do not fulfil the strict criteria set here. Finally, if the inclusion criteria are widened to include peer-reviewed studies that assessed dose–response relationships between objective indicators of exposure and the subjective (self-reported) prevalence of diseases, a further two studies can be considered. These are the cross-sectional study carried out in Stockholm regarding the association between aircraft noise and hypertension (Rosenlund et al., 2001), and the cross-sectional part of the study in Berlin regarding the association between road traffic noise and myocardial infarction (Babisch et al., 1994). Fig. 4.4 shows the results of the three aircraft noise studies carried out in Amsterdam, Okinawa and Stockholm (Knipschild, 1977a; Rosenlund et al., 2001; Matsui et al., 2004). The graph clearly indicates that the results are too heterogeneous to derive a pooled dose–response curve. However, all three studies show an increase in risk with increasing noise level.

Studies that are not given a high ranking according to the above mentioned criteria, however, may serve as additional sources of information to support the evidence of the conclusions being made on the basis of this review. This is illustrated in Fig. 4.5. The entries are relative risks (centre of the bars) with 95% confidence intervals (the bars) for dichotomous comparisons of noise exposure (extreme groups or high vs. low). A relative consistent shift of the bars to relative risks greater than 1 can be seen. The dark-shaded bars in the diagram refer to studies where the noise exposure was determined objectively (noise levels), the

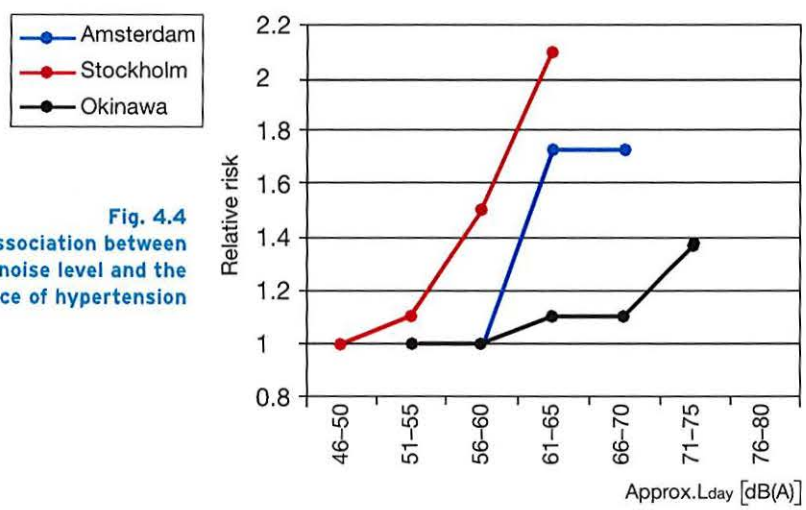



**Fig. 4.4**
**Association between aircraft noise level and the prevalence of hypertension**



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light-shaded bars where it was determined subjectively (annoyance). Road traffic and aircraft noise studies are here viewed together. No corresponding results are available for rail traffic studies. If different subgroups of the population (males/females) or different health end points were taken into account, specific studies appear more than once in the illustration.

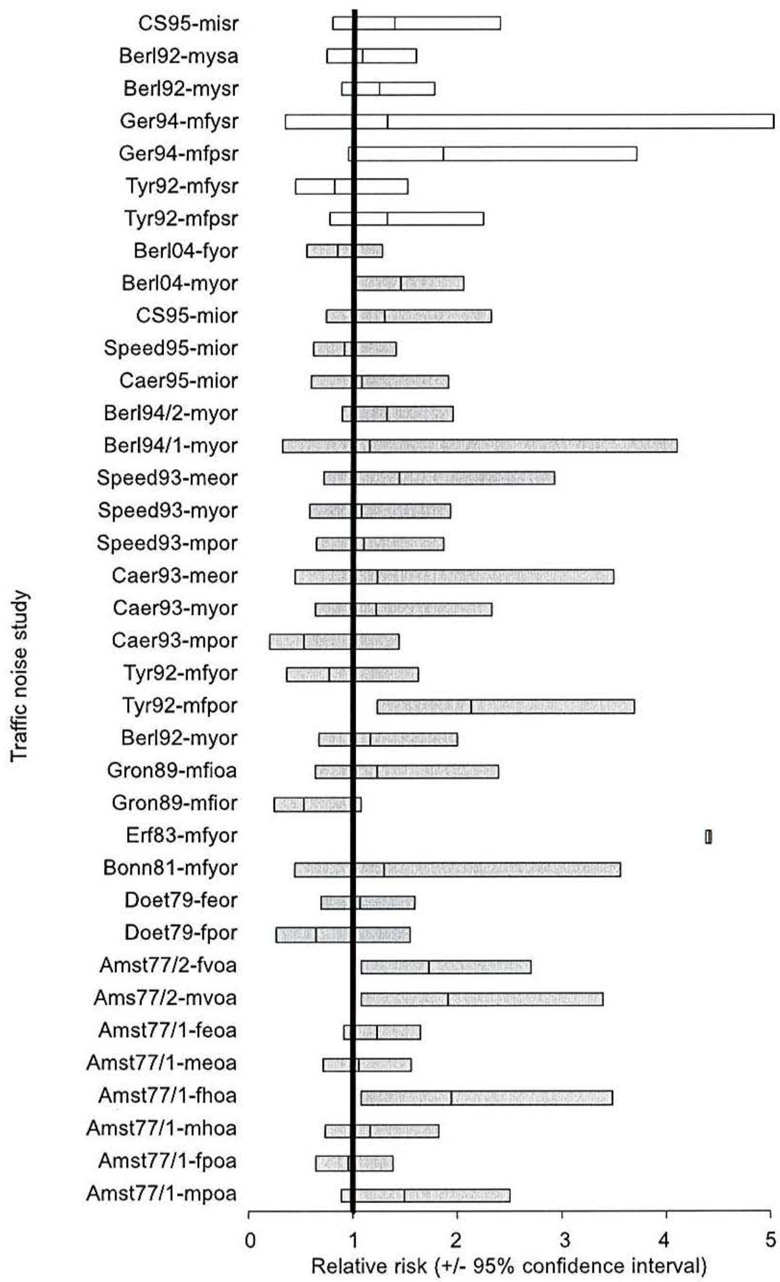



**Fig. 4.5**
**Results of epidemiological studies on the association between traffic noise and ischaemic heart disease**

*Captions: sex: f = female, m = male; noise measurement: o = objective (sound level), dark-shaded beam; s = subjective (annoyance), light-shaded beam; type of noise: a = aircraft noise; r = road traffic noise; ischaemic heart disease: e = ECG-ischaemic signs, h = heart complaints, i = ischaemic heart disease, p = angina pectoris, v = cardiovascular complaints in general, y = heart attack.*

*Source: Babisch, 2002, modified according to the results of Babisch, 2004b.*

## 4.5.10 DOSE-RESPONSE CURVE: META-ANALYSIS

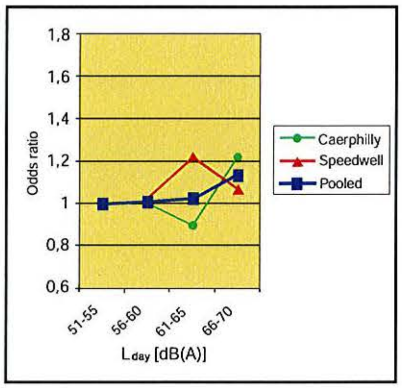
For a quantitative risk assessment and the derivation of guidelines for public health noise policy a common dose–response curve is required. The risk estimates obtained from different noise studies can be summarized using the statistical approach of a meta-analysis. Based on the judgement criteria discussed in section 4.5.9.2, five analytic and two descriptive studies emerged that can be used to derive a common dose–response curve for the association between road traffic noise and the risk of myocardial infarction. Two separate meta-analyses were made by considering the analytic studies that were carried out in Caerphilly and Speedwell (cohort studies) and Berlin (case-control studies) on the one hand, and the descriptive studies that were carried out in Caerphilly and Speedwell (cross-sectional studies) on the other hand. It turned out, as a result of the evaluation, that all these studies referred to road traffic noise during the day ($L_{day}$: 06.00–22.00) and the incidence or prevalence of myocardial infarction as the outcome. Study subjects were men. In all analytic studies the orientation of rooms was considered for the exposure assessment (facing the street or not). With respect to the Caerphilly and Speedwell studies, the six years of pooled follow-up data provided the respective information. In all descriptive studies the traffic noise level referred to the facades that were facing the street and did not consider the orientation of rooms/windows. All individual effect estimates were adjusted for the covariates considered in each of the studies. Different sets of covariates were considered in each study. However, this pragmatic approach accounts best for possible confounding in each study and provides the most reliable effect estimates derived from each study. The concept of meta-analysis was used to aggregate and summarize the findings of the different studies (Olkin, 1995; Blettner et al., 1999). The program "meta" was downloaded from the "STATA" web site for use in the statistical package STATA (version 8.0), and for calculating the pooled random effect estimates.

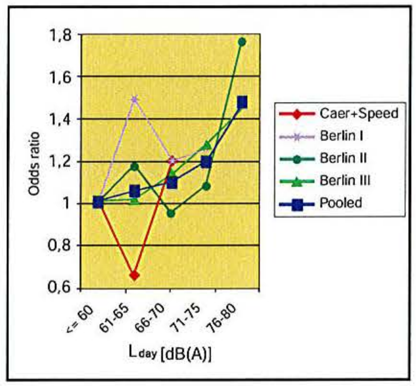
**Table 4.2**
**Single and pooled (meta-analysis) effect estimates (odds ratios and 95% confidence intervals) of descriptive and analytic studies on the relationship between road traffic noise level ($L_{day}$) and the incidence/prevalence of myocardial infarction**

| | Road traffic noise level - $L_{day}$ [dB(A)] | | | | | |
|---|---|---|---|---|---|---|
| **Descriptive studies** | **51-55** | **56-60** | **61-65** | **66-70** | | **N** |
| Caerphilly | 1.00 | 1.00 (0.58-1.71),[13.29] | 0.90 (0.56-1.44),[17.23] | 1.22 (0.63-2.35),[ 8.98] | | 2512 |
| Speedwell | 1.00 | 1.02 (0.57-1.83),[11.19] | 1.22 (0.70-2.21),[12.62] | 1.07 (0.59-1.94),[10.94] | | 2348 |
| Pooled | 1.00 | 1.01 (0.68-1.50) | 1.02 (072-1.47) | 1.14 (0.73-1.76) | | |
| Q-Test | | p=0.96 | p=0.41 | p=0.77 | | |
| **Analytic studies** | **60** | **61-65** | **66-70** | **71-75** | **76-80** | **N** |
| Caerphilly + Speedwell | 1.00 | 0.65 (0.27-1.57),[ 4.95] | 1.18 (0.74-1.89),[17.48] | --- | --- | 3950 |
| Berlin I | 1.00 | 1.48 (0.57-3.85),[ 4.21] | 1.19 (0.49-2.87),[ 4.94] | 1.25 (0.41-3.81),[ 3.09] | 1.76 (0.11-28.5),[0.50] | 243 |
| Berlin II | 1.00 | 1.16 (0.82-1.65),[31.43] | 0.94 (0.62-1.42),[22.76] | 1.07 (0.68-1.68),[18.92] | 1.46 (0.77-2.78),[9.27] | 4035 |
| Berlin III | 1.00 | 1.01 (0.77-1.32),[54.42] | 1.13 (0.86-1.49),[50.87] | 1.27 (0.88-1.84),[28.24] | --- | 4115 |
| Pooled | 1.00 | 1.05 (0.86-1.29) | 1.09 (0.90-1.34) | 1.19 (0.90-1.57) | 1.47 (0.79-2.76) | |
| Q-Test | | p=0.57 | p=0.87 | p=0.84 | p=0.90 | |

Table 4.2 shows individual and pooled effect estimates with confidence intervals (rounded brackets), statistical weights (square brackets) for the individual studies, and the Q-test of heterogeneity between studies. According to the Q-test, the nil hypothesis of non-heterogeneity was never discarded. Figs 4.6 and 4.7 show odds ratios of individual studies and the pooled estimates for the descriptive and analytic studies.

**Fig. 4.6 and Fig. 4.7**
**Single and pooled effect estimates (odds ratios) for the descriptive and analytic studies of the association between road traffic noise level and the prevalence (left graph) and incidence (right graph), respectively, of myocardial infarction**




## 4.5.11 EFFECT MODIFICATION

Support for any noise–effect relationship may come from subgroup analyses that are in line with the noise hypothesis. This refers to effect modification with respect to residence time, window-opening behaviour and other determinants that affect the noise exposure and cumulative noise dose. In the Amsterdam aircraft noise studies, a steady increase in the purchase of cardiovascular and antihypertensive drugs at local pharmacies was found over the period of eight years in a community newly exposed to aircraft noise. No such increase was found in a control community that was not exposed to aircraft noise (Knipschild and Oudshoorn, 1977). Positive associations between the prevalence of cardiovascular diseases and residence time in exposed areas (but not in unexposed) were also found in the road traffic noise studies carried out in Bonn with respect to hypertension (Eiff and Neus, 1980; Neus et al., 1983) and in Caerphilly and Speedwell with respect to IHD (Babisch et al., 1999; Babisch, Ising and Gallacher, 2003). When the analyses of the road traffic noise studies carried out in Berlin, Caerphilly and Speedwell were restricted to subjects who had not moved within a retrospective period of 10–15 years, the effect estimates turned out to be larger than for the total samples of each study (Babisch et al., 1994, 1999, 2005). Similarly, a larger effect was found in the study in Sollentuna with respect to hypertension (Bluhm, Nordling and Berglind, 2001). No such effect was found in the Lübeck study (Hense, Herbold and Honig, 1989; Herbold, Hense and Keil, 1989). The cross-sectional data of the study carried out in Los Angeles on children regarding mean BP indicated some habituation to aircraft noise (Cohen et al., 1980). The longer the children were enrolled in the school, the smaller was the difference in BP between exposed and non-exposed children.

However, the follow-up study suggested that this may also be an effect of attrition (Cohen et al., 1981). The longer the families experienced the noise, the more likely that they moved away from the exposed areas (selection bias). In contradiction to this, BP differences between children exposed and not exposed to road traffic noise increased with school grade (Karsdorf and Klappach, 1968). Intervention studies were conducted with respect to changes in BP and changes in air traffic operation (for example the opening/closing of airports or runways). In the Munich study, a larger increase in BP was found in children from a noisy area (Evans, Bullinger and Hygge, 1998). Other studies suggested reversible effects on BP when the exposure was lowered (Wölke et al., 1990; Morrell et al., 1998, 2000). In the Tyrol study, significantly lower BP readings were found in subjects who kept the windows closed throughout the night (Lercher and Kofler, 1993, 1996). When the subjects lived close to the highway (within a distance of approximately 500 metres), the prevalence of hypertension was higher in subjects whose bedroom was facing the main road than in those whose bedroom was not facing the main road. The orientation of rooms and window opening was also found to be an effect modifier of the association between road traffic noise and IHD in the Caerphilly and Speedwell studies (Babisch et al., 1999). The relative risk with respect to the noise level was slightly higher in subjects with rooms facing the street and subjects keeping the windows usually open when spending time in the room. A much greater relative risk of hypertension was found in subjects who slept with open bedroom windows in the Spandau Health Survey (Maschke, 2003; Maschke, Wolf and Leitmann, 2003). Hearing impairment was found to be an effect modifier on the association between aircraft noise and hypertension (Rosenlund et al., 2001). Amongst the exposed subjects, a higher risk associated with the noise was only found in subjects without hearing loss.

## 4.5.12 EXPOSURE DURING THE NIGHT

Unfortunately, epidemiological noise research provides nearly no information regarding the particular impact of noise exposure during the night on cardiovascular health outcomes. The Spandau Health Survey explicitly distinguished between the exposure of the living room (during the day) and the exposure of the bedroom (during the night). There, a slightly higher relative risk of hypertension was found with respect to the traffic noise level during the night (relative risk 1.9 vs. 1.5) compared with the noise level during the day (Maschke, 2003; Maschke, Wolf and Leitmann, 2003). Furthermore, sleeping with open bedroom windows was associated with a large increase in risk. However, due to the small sample size, the confidence intervals were very large. In the drug survey of the Amsterdam aircraft noise studies, a steady increase in purchase of hypnotics (sleeping pills) and sedatives was found (Knipschild and Oudshoorn, 1977). This trend decreased considerably when night flights were largely banned. Such a decrease was not found regarding cardiovascular drugs for which the purchase also increased over time. However, this may partly be due to the fact that atherosclerotic manifestations of high BP were less reversible (in contrast to vasoconstriction, which is more related to acute or semi-acute effects, for instance in children). It was mentioned in the previous section that closing the windows had a protective effect on BP readings in the Tyrol study (Lercher and Kofler, 1993). This was only found regarding closing the windows during the night and not during the day. Furthermore, subjects who had switched the bedroom and the living room because of the noise had a significantly lower BP than those who did not do so. The findings are discussed in a broader context of coping strategies (Lercher, 1996). When subjective responses to community noise were considered, higher relative risks of cardiovascular diseases were found for noise-related disturbances of sleep and relaxation, rather than for other disturbances or subjective descriptors of noise exposure, which did not refer to the night-time. This was found in the Caerphilly and Speedwell studies (Babisch, Ising and Gallacher, 2003), the NaRoMI study (Babisch et al., 2005), the Spandau Health Survey (Maschke, Wolf and Leitmann, 2003) and a general population sample of Germany (Bellach et al., 1995). The LARES study (Niemann and Maschke, 2004), in which noise-induced sleep disturbance was assessed, did not show a higher relative risk compared with the general annoyance.

## 4.5.13 RISK GROUPS

Most epidemiological noise studies looked at the cardiovascular effects of community noise in men. This may simply be due to the fact that the prevalence of cardiovascular diseases in middle-aged subjects is higher in men than in women. Statistical power is an important issue for the design of a study. Furthermore, in noise experiments, physiological reactions controlled by the autonomic nervous system were less pronounced in females than in males (Neus et al., 1980; Ising and Braun, 2000). Improper control for possible differential effects of the intake of sex hormones, including contraceptives, which may prevent or promote adverse (noise) stress effects, may act conservatively on the results (Cairns et al., 1985; Eiff, 1993; Farley et al., 1998). The studies carried out in Lübeck (Hense, Herbold and Honig, 1989; Herbold, Hense and Keil, 1989), Pancevo (Belojevic and Saric-Tanaskovic, 2002), Berlin (Babisch et al., 2005), Stockholm (Rosenlund et al., 2001), a German population sample (Bellach et al., 1995), Bonn (residence time) (Eiff and Neus, 1980; Eiff et al., 1981b) and in Amsterdam (angina pectoris) (Knipschild, 1977a) found higher prevalences of hypertension, IHD and the use of cardiovascular drugs in noise-exposed men than in women. The studies carried out in Bonn (sound level) (Eiff and Neus, 1980; Eiff et al., 1981b), Sollentuna and Amsterdam (heart trouble) (Knipschild, 1977a; Bluhm, Nordling and Berglind, 2001) found the opposite. In the studies carried out in the former Soviet Union, it was reported that noise effects on the cardiovascular system were more pronounced in young and middle-aged subjects (Karagodina et al., 1969). Swedish noise studies (Bluhm, Nordling and Berglind, 2001, 2004) and the LARES study (Niemann and Maschke, 2004) found similar results. The opposite (larger effects in elderly subjects) was reported from the Amsterdam study (Knipschild, 1977a) and the Stockholm study (Rosenlund et al., 2001). The available database on cardiovascular effects of noise in children is poor. No data are available that refer, in particular, to noise and sleep. The quantitative impact of transportation noise on the cardiovascular system is still a matter of research. A quantitative health risk assessment for children cannot be made at the moment.

Based on the available information from noise studies, it must be concluded that children do not appear to be a particular risk group with respect to cardiovascular outcomes, especially BP. This does not mean that the literature does not suggest higher BP readings in children. It only means that the effect in children does not appear to be different than that in adults. However, children may be exposed longer to noise throughout their lifetime than the adults that have been studied. No long-term follow-up studies are known that focus on noise exposure. Most studies on children considered noise in schools rather than noise at home, which implies different mechanisms about how noise could contribute to a rise in BP (raised effort in learning/speech perception vs. disturbed relaxation/sleep). The prospective part of the Caerphilly and Speedwell studies gave a small hint that health status could be a modifying factor. In subjects with prevalent chronic diseases, road traffic noise was associated with a slightly larger increase in the incidence (new cases) of IHD than in subjects without prevalent diseases – when the objective noise level was considered (Babisch et al., 2003). Surprisingly, when annoyance and disturbances due to traffic noise were considered for exposure, the opposite was found. Noise effects were only seen in subjects without prevalent diseases. This was discussed with respect to reporting bias.

### 4.5.14 RISK EVALUATION

The process of risk assessment (risk evaluation) comprises hazard identification ("Which health outcome is relevant for the exposure?"), exposure assessment ("How many are affected?") and dose–response assessment ("threshold of effect"). This information is summarized in "risk characterization" ("health hazard characterization"). It involves the interpretation of the available evidence from the available data and other scientific disciplines, and is subject to discussion of the uncertainties. These include chance, bias and validity of studies as well as transparency, replicability and comprehensiveness of reviews. As a result of the risk evaluation process, a quantitative estimate about the likelihood that the hazard will affect exposed people will be derived. Usually, attributable risk percentages are calculated (Walter, 1998). This will serve as key information for any kind of risk management including regulatory options (Jasanoff, 1993). The term "adverse" is essential in this context of environmental standard setting. Risk management should ensure that "adverse" health effects do not occur. The fact that an organism responds to noise does not have to be per se "adverse". The severity of a health outcome is an important determinant of the adversity of an effect and implies variable action levels for public health policy (Babisch, 2002, 2004a; Griefahn et al., 2002; Health Council of the Netherlands, 2003). Since considerable parts of the population are exposed to high noise levels (EEA, 2004), noise policy can have a significant impact on public health (Neus and Boikat, 2000). Due to the increasing number of people affected with the decreasing severity of the effect, even small individual risks and less severe health outcomes can be relevant for public health and decision-making. It has been shown that moderate noise exposures implying a small individual risk may cause more noise-induced cases of health-impaired subjects than higher noise exposures. Franssen et al. (2004) pointed out that the number of people suffering from poor health due to aircraft noise is dominated by the larger number of people that is exposed to relatively moderate-to-low noise levels and not by those exposed to high noise levels. This means that more emphasis should be put on the reduction of noise in moderately exposed areas. However, public health policy cannot only consider population attributable risks (risk percentages), but must also consider individual risks (lifetime risk).

In practice, it seems to be reasonable that noise policy should reduce noise, beginning with the highest exposures and ending with the lowest ones. Decision-making will have to find common standards of acceptable risks, which may vary according to the cost–benefit considerations within and between communities and countries. Such practical standards may, however, vary due to economic development and abilities, cost–benefit considerations and priority settings of a community or country. Health quality targets derived from scientific research are usually intended to minimize risks; decision-making in the political process is only partly scientifically based due to economic limitations and concurring interests (Nijland et al., 2003). Different health outcomes or indicators of well-being and quality of life imply different action levels. Environment and health policy must determine acceptable noise standards that consider the whole spectrum from subjective well-being to somatic health (for example annoyance, physiological arousal, health risk). The evidence for a causal relationship between community or transportation noise and cardiovascular risk appears to have increased over recent years due to new studies that accomplish the database.

## 4.5.15 CONCLUSIONS

The evaluation process used in this paper considered the "necessary" criteria: peer-reviewed publication in an international journal, reasonable quantitative control of possible confounding, objective assessment of exposure and outcome, type of study (analytic vs. descriptive), and dose–response assessment (not only dichotomous "high" vs. "low"). The approach differs from that of an earlier meta-analysis (van Kempen et al., 2002) in that there regression coefficients were calculated for the entire dose–response curve within a single study (for instance the increase in risk per 5 dB(A)), which were then pooled between studies. Since higher exposure categories usually consist of smaller numbers of subjects than the lower categories, regression coefficients across noise levels tend to be influenced by the lower categories. This may lead to an underestimation of the risk in higher noise categories. The approach presented here pooled the effect estimates of single studies within each noise category, thus giving more weight to the higher noise categories and accounting for possible non-linear associations.

**Fig. 4.8 and Fig. 4.9**
**Pooled effect estimates (meta analysis) of descriptive and analytic noise studies of the association between road traffic noise level and the prevalence (left graph) and incidence (right graph), respectively, of myocardial infarction (odds ratio ± 95% confidence interval).**

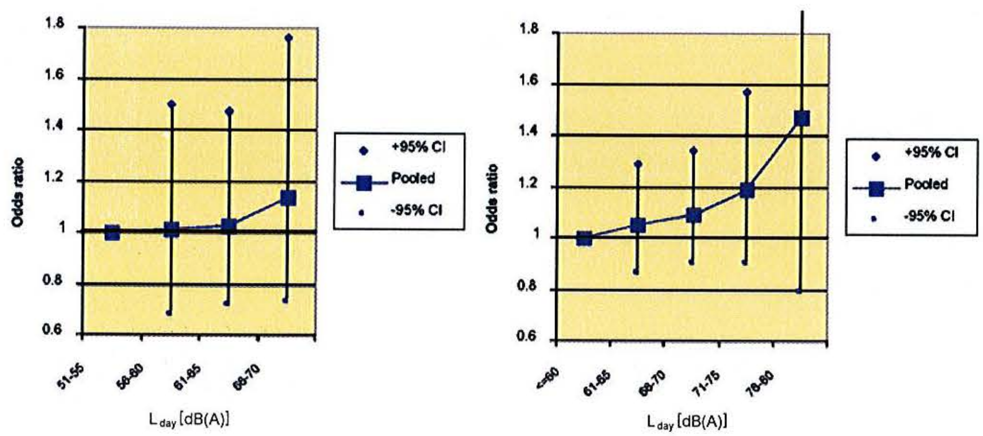



Fig. 4.8 and Fig. 4.9 show the two risk curves for descriptive and analytic studies (Hennekens and Buring, 1987). The graphs show the pooled effect estimates (odds ratios) and the 95% confidence intervals for each noise category. Whereas the cross-sectional studies (Fig. 4.9) cover the sound level range of $L_{day}$ from >50 to 70 dB(A), the cohort and case-control studies (Fig. 4.8) cover the range from ≤60 to 80 dB(A). Both curves together can serve as a basis for a quantitative risk assessment. From Fig. 4.8 it can be seen that below 60 dB(A) for $L_{day}$ no noticeable increase in risk of myocardial infarction is to be detected. Therefore for the time being, $L_{day}$ = 60 dB(A) can be seen as NOAEL (no observed adverse effect level) for the relationship between road traffic noise and myocardial infarction (Babisch, 2002). For noise levels greater than 60 dB(A), the risk of myocardial infarction increases continuously, and is greater than 1.2 for noise levels of 70 dB(A). This can be seen in Fig. 4.9. It should be mentioned that the risk estimates, in general, were found to be higher in subjects that had lived in the exposed areas for a longer time (Babisch et al., 1994, 1999, 2005). This is in accordance with the noise hypothesis and the effects of chronic noise stress (Lercher and Kofler, 1996; Thompson, 1997). However, for the calculation of population attributable risks the figures for the whole population are relevant due to unknown information about residence time.

No particular risk groups could be identified on the basis of epidemiological research on cardiovascular effects of community noise. The assessment of dose-effect relationships sometimes suggested a cut-off level, above which the risk tends to increase. From a biological point of view, one would expect a continuous increase in risk with increasing noise level. However, adaptation, habituation and coping may be reasons for an empirical threshold of effect. Decisions with respect to guideline values usually refer to a quantitative risk assessment of populations (for example population attributable risk percentage). However, prevention strategies – for ethical reasons – should not ignore the individual risks of highly exposed subjects, even if their number may be small.

With respect to night noise exposure, nearly no information is available from epidemiological studies on the cardiovascular effects of long-term noise exposure of the bedroom during the night. Only one study distinguished between the exposures of the bedroom and the living room in the statistical analyses (Maschke, Wolf and Leitmann, 2003). The results suggested slightly higher effect estimates for the prevalence of hypertension with respect to the noise exposure of the bedroom (during the night) compared with the exposure of the living room (during the day). However, the difference was small (odds ration 1.9 vs. 1.5), which means that it still remains an open question whether the night exposure or the overall exposure throughout the whole day is the driving force. The study has some methodological limitations that were addressed in the summary of the major technical report and in a recent advisory report of the Health Council of the Netherlands (2004). They are mainly concerned with the fact that the study population consisted of a selected, predominantly older and health conscious group of persons that might have already suffered from regular health problems (risk group). A few studies that looked at the association between subjective responses to community noise and cardiovascular outcomes suggest a closer relationship with sleep-related annoyance/disturbance reaction rather than with non-sleep-related annoyance/disturbance (Bellach et al., 1995; Babisch et al., 1999, 2005; Maschke, Wolf and Leitmann, 2003; Niemann and Maschke, 2004). Closing the bedroom window or, vice versa, sleeping with the bedroom window open, was associated with a lower or higher risk, respectively (Lercher, 1996). The same was found with respect to changing the bedroom to the living room because of noise. These findings may indicate that night-time noise may be more a determinant of noise-induced cardiovascular effects than daytime exposure. However, daytime activity patterns and expectations of the individuals are much more inhomogeneous than during the night, which tends to dilute the statistical association of true effects with the day noise exposure.

Given the situation that only a few data are available from epidemiological studies with respect to effects on sleep (exposure of the bedroom during the night), there does not seem to be any other way of reasoning than inferring night noise recommendations or guidelines from the results of studies that refer to noise exposure during the daytime period ($L_{day}$) or the whole day ($L_{dn}$, $L_{24h}$). $L_{den}$, in this context, appears to be a useful noise indicator for decision-making and regulatory purposes. Penalties of 5 dB(A) and 10 dB(A) are usually given to the evening period and the night period, respectively. It can be used for noise mapping and refers normally to the most exposed facade, which incorporates a certain degree of exposure misclassification regarding cause–effect relationships. This weighted indicator was introduced to assess the relationship between sound level and noise annoyance (European Commission, 2002a). However, it may not be adequate for research into (somatic) health-related noise effects. Non-weighted separate exposure indicators, such as $L_{day}$, $L_{evening}$ or $L_{night}$, may be more appropriate when assessing physiological responses to the noise. In urban settings, night-time average noise levels (22.00–06.00) for road traffic tend to be approximately 7–10 dB(A) lower than daytime average noise levels – relatively independent (no freeways) of the traffic volume of the street (Utley, 1985; Ullrich, 1998; Evans et al., 2001). In such cases, $L_{den}$ is approximately 2–3 dB(A) higher than $L_{day}$ (Bite and Bite, 2004). Therefore, in epidemiological studies in which the relative effects of road traffic noise are studied, the sound emission during the daytime can as well be viewed as an approximate relative measure of the overall sound emission including the night. This seems to be further justified because existing noise regulations usually consider a 10 dB(A) difference between the day and the night. The NOAEL of 60 dB(A) for $L_{day}$ corresponds, in this respect, with 50 dB(A) for $L_{night}$. This approximation can only be made with respect to road traffic noise.

Aircraft noise has been less intensively studied in noise epidemiology. The studies focused on high BP. Dose–response curves were hardly considered. A large European study on the association between aircraft noise and road traffic noise on BP is currently being conducted (Jarup et al., 2003). Regarding aircraft noise – and particularly the ongoing debate on night flight restrictions in the vicinity of busy airports – no other alternative exists at present than to take the myocardial infarction risk curves derived from road traffic noise studies as an approximate for aircraft noise. Since aircraft noise acts on all sides of a building, that is, different to road traffic noise, the suspicion exists that the effects induced by aircraft noise could be greater than those induced by road traffic (Ortscheid and Wende, 2000; Babisch, 2004a). This may be due to the lack of evasive possibilities within the home and the greater annoyance reactions to aircraft noise, which are usually expressed in social surveys (Miedema and Vos, 1998). More research is needed regarding the association between aircraft noise and cardiovascular end points.

This section is clearly focused on ill health as an outcome of the adverse effect of noise. A common dose-effect curve for the relationship between road traffic noise (outdoors) and the risk of myocardial infarction was developed. This curve can be used for a quantitative risk assessment and the calculation of attributable cases in a community. However, decisions regarding limit values have to be made within the spectrum between discomfort (annoyance) and ill health (disease) (Lindström, 1992; Babisch, 2002). Whereas quality targets at the lower end of the effects scale may be more flexible, quality targets at the upper end may be more obligatory. For example, for ethical reasons (equality principle) it does not seem to be justified if (ill) health-based limit values are varied according to the type of living area as expressed in land development plans (for example residential, mixed or commercial).

## 4.6 INSOMNIA

A group of Japanese researchers carried out a questionnaire-based survey of 3600 adult Japanese women (aged between 20 and 80) to gather information about the factors that contribute to insomnia (Kageyama et al., 1997). Some 11% of subjects were found to be affected by insomnia (as defined on the basis of WHO's International Statistical Classification and Related Health Problems, 10th revision – ICD10). Analysis of the survey data took account of various distorting variables, such as age, number of (small) children in the family, social status, receipt of medical treatment, regularity of bedtimes, apnoea-like problems and serious unpleasant experiences in the six months prior to completing the questionnaire. When the percentage of insomniacs in each of the three areas with the highest exposures was compared with the percentage in the low-exposure areas, the ratios worked out at, respectively, 1.4 (2100 vehicles per hour, $L_{night}$ of around 65 dB(A)), 2.1 (2400 vehicles per hour, $L_{night}$ of around 67 dB(A)) and 2.8 (6000 vehicles per hour, $L_{night}$ of around 70 dB(A)). The most frequently reported problem was difficulty getting to sleep.

Research into the effects of exposure to air and road traffic noise has shown that increases in night-time noise exposure or in noise exposure during the sleep latency period have a statistically significant adverse impact on subjects' ability to get off to sleep and on sleep inception periods.

## 4.7 EFFECTS ON PERFORMANCE

### 4.7.1 COGNITION AND SWS

Jan Born and co-workers at the University of Lübeck (Wagner, Gais and Born, 2001; Benedict et al., 2004; Born and Wagner, 2004; Gais and Born, 2004; Drosopoulos, Wagner and Born, 2005) have reported interesting research and put forward intriguing hypotheses on the relation between noise exposure, sleep loss and subsequent cognitive performance. They conclude that declarative memory benefits mainly from sleep periods dominated by SWS, while there is no consistent benefit for this memory from periods rich in REM sleep. This points to the importance of SWS for declarative memory.

Since sleep in the early night is dominated by SWS, in contrast to late night when REM sleep dominates, this would imply that noise in the early night, for example aircraft noise before midnight, would be particularly damaging to memory and related cognitive functions. However, this implication has not yet been explicitly tested. That is, there seems to be a certain risk for impoverished memory due to noise in the early night, but there is as yet no graded quantification about whether ordinary pre-midnight noise levels around large airports are sufficient to make a difference to SWS. We also lack graded quantification about the relationship between impoverished SWS and the resulting effect on different aspects of declarative memory.

Thus, in terms of Fig. 1.1 we have evidence for the arrow marked (b), but we do not have enough information to say whether the strength of arrow (a) is sufficient to cause reduced SWS in field settings.

Furthermore, since children's memory systems pass through developmental changes and are not structured in the same way as for adults, it would be interesting to know to what extent the Born group results are also valid for children, and whether the depth of children's sleep counteracts or enhances SWS dominance in the early night.

### 4.7.2 COMPARING DAYTIME AND NIGHT-TIME NOISE EXPOSURE

As implied by Fig. 1.1, the relation between noise exposure and resulting effects on cognition should be analysed somewhat differently depending on whether the noise exposure takes place during the day or night. Analysing the cognitive effects of daytime noise exposure is fairly straightforward. For night-time noise exposure, however, any effects on cognition can either be a more or less direct effect of the noise exposure, or an indirect effect mediated by reduced sleep or sleep quality.

Also, comparing, for example, memory and learning functions when exposed to night-time noise, in contrast to daytime noise, shifts the focus of analysis away from encoding (in memory) or acquisition (in learning) while experiencing noise, to a focus on storing the material to be remembered or learnt while asleep (compare to daytime noise effects on cognition as reported by Hygge, Evans and Bullinger, 2002; Stansfeld et al., 2005). Thus, assuming that people are mainly asleep at night, all cognitive work that relies on the intake of information, listening or reading is not relevant. In all, this suggests that studies of daytime noise levels cannot be used much to give rough estimates of the effects of night-time exposure.

### 4.7.3 COMPARING CHILDREN AND ADULTS

How far can effects of daytime noise levels on children be generalized to give a rough estimate of the effects on adults? Are children more sensitive? Judging from earlier daytime studies of children and adults doing the same cognitive tasks while exposed to noise, children are not more sensitive than adults to noise (Boman, Enmarker and Hygge, 2004), but they perform at a lower level than the adults both in noisy and in quiet environments. Thus, it could be said that children are not more vulnerable to (daytime) noise in relation to cognitive performance, but since so much more cognitive work is expected from children while in school, their learning environment and their cognitive tasks can be said to be more noise vulnerable than corresponding environments for adults.

### 4.7.4 NOISE AND AFTER-EFFECTS

An argument can be made for noise as a stressor leading to reduced motivation (Glass and Singer, 1972), which in turn may act as a mediator of impaired cognitive performance. Along this line of reasoning, night-time noise may be more potent in inducing reduced motivation than daytime noise, but for the time being this is only a conjecture and has not been tested.

#### *4.7.4.1 The role of restoration*

Noise can be viewed both as a source of stressful demands and as a constraint on restoration. Noise levels and noise sources that are not by themselves particularly demanding during the waking hours of the day, may nevertheless be quite effective in blocking and constraining when they appear in periods meant to be restorative, such as sleep (Hartig, 2004). To what extent this idea is applicable to night-time noise exposure has not yet been explored.

#### *4.7.4.2 Noise and communication*

Some of the difficulties with children's responses to noise are related to problems in speech perception. A metric that weights night-time exposure more heavily is, in fact, less useful since children's auditory processing with parents and teachers is obviously more critical during waking hours.

## 4.8 EFFECTS ON PSYCHIC DISORDERS

Noise exposure at night may be more disturbing than daytime noise because it interferes with rest and sleep at a time when people want to relax. It seems plausible that night-time noise might have a particular effect on mental health. However, there is little direct research into night-time noise and mental health and it is first necessary to consider the evidence for environmental noise and mental health in general. The association between noise and mental health has been examined using a variety of outcomes including (at the simplest level) individual symptoms, as well as psychiatric hospital admission rates, use of health services and psychotropic medication, and community surveys.

## 4.8.1 TRANSPORTATION NOISE AND MENTAL HEALTH

Sources of transportation noise that have been studied in relation to mental health include road traffic noise and aircraft noise. Studies relating to each type of noise will be considered in turn.

### *4.8.1.1 Road traffic noise*

The association between road traffic noise exposure and psychological distress has been studied in the small town of Caerphilly, South Wales. In the cross-sectional results, no association was found between the initial level of road traffic noise based on traffic noise maps, in terms of $L_{eq}$ referring to the period 06.00–22.00, and minor psychological distress, measured by the General Health Questionnaire (GHQ), a screening questionnaire for depression and anxiety, even after adjustment for sociodemographic factors (Stansfeld et al, 1993). In longitudinal analyses in the Caerphilly Study, no association was found between road traffic noise and psychological distress, even after adjustment for sociodemographic factors and baseline psychological distress, although there was a small non-linear association of noise with increased anxiety scores (Stansfeld et al, 1996).

The disadvantage of the Caerphilly study is that it relied on one location with not very high levels of traffic noise. In a secondary analysis of a large British road traffic noise study, which took into account multiple noise exposure sites, the noise level in dB(A) exceeded for 10% of the time was weakly associated with a mental health symptoms scale of five items adjusting for age, sex, income and length of residence (Halpern, 1995). Weaker associations between traffic density and the mental health symptoms scale may relate to the skewed distribution of this traffic density variable. It seemed that traffic noise was more important than traffic flow. The scale used included some clear mental health items but also some that were less obviously related to mental health. It may be questioned whether the reported association between noise level and mental health symptoms was actually due to noise exposure; adjustment for the amount of "noise heard" reduced the association very little, suggesting no causal association with noise, but it is likely that there was a good deal of error in the measurement of this variable, reducing its validity.

It may be that the peak noise level is a better indicator of environmental noise heard indoors than noise measures averaged over time and that peak levels are a crucial indicator for mental health. Furthermore, in a road traffic noise study in Belgrade, 253 residents exposed to road traffic noise levels of >65dB(A), with high levels both day and night ($L_{eq}$ 76.5 in the day, 69.5 at night in the noise-exposed area), experienced significantly more fatigue, depression, nervousness and headaches, compared to residents exposed to <55dB(A) (Belojevic and Jakovljevic, 1997). Sleep quality was also found to be worse among the inhabitants of noisy streets, compared to inhabitants of quiet streets, and those living in noisy streets had more difficulties falling asleep, more night awakenings and more pronounced tiredness after sleep. However, there were no differences in time taken to fall asleep or to go back to sleep, duration of sleep or consumption of sleeping pills between noise-exposed and non-exposed residents. A great methodological advantage of this study was that the high and low noise exposure areas were homogenous for age, sex, employment and subjective noise sensitivity. A community study in 366 Japanese women suggests that road traffic noise only has effects on depression, fatigue and irritability above a threshold of 70 dB(A) (Yoshida et al., 1997). However, it is difficult to be confident of the results of these analyses as they were unadjusted for age or social deprivation. Milder psychological states such as health functioning and well-being have also been examined in the first stage of an intervention study on the effect of introducing a bypass to relieve traffic congestion in a small town in North Wales (Stansfeld, Haines and Brown, 2000). Health functioning was measured by the SF-36 General Health Survey (Ware and Sherbourne, 1992), including dimensions of general health status, physical functioning, general mental health and social functioning. Ninety-eight respondents were studied who lived on a busy high street with traffic noise levels varying between 72 and 75 dBA outdoor $L_{eq}$. These respondents were compared with 239 control subjects living in adjacent quieter streets (noise level 55–63 dB(A) outdoor $L_{eq}$). Although subjects were well-matched on age, sex, housing insulation, car ownership and employment status, they were not so well-matched on proportion of manual workers, household crowding, deprivation and home ownership. There was no evidence that respondents exposed to higher levels of road traffic noise had worse health functioning than those exposed to lower levels of the noise, adjusting for levels of deprivation.

Another method of assessing mental health effects related to noise exposure is to use an indirect indicator such as medication use. In five rural Austrian communities exposed to road traffic noise, noise levels above 55 dB(A), including increasing night-time exposure to noise from trucks, were associated with increased risk of taking sleeping tablets (OR = 2.22 [CI: 1.13–4.38]) and overall prescriptions (OR = 3.65 [CI: 2.13–6.26]) relative to road traffic noise exposure less than 55 dB(A) (Lercher, 1996). This suggested effects at fairly low noise levels. In this case mental ill health may be secondary to sleep disturbance, which is likely to occur at lower nocturnal noise levels than mental health symptoms resulting from daytime noise exposure. As this occurred in a rural setting where road traffic was the predominant source of noise it would be interesting to replicate these findings in other settings.

#### *4.8.1.2 Road traffic noise and mental health in children*

Noise exposure and mental health has also been studied in children where child self-reported mental health on a standard scale and teacher ratings of classroom adjustment in response to motorway, road and rail noise were measured in a large sample of 8–11-year-old Austrian primary school children and in a second stage sample of extreme noise-exposed groups. Noise exposure was significantly associated with classroom adjustment scores but, intriguingly, child self-reported mental ill health was only impaired in noisy settings for children of low birth weight and preterm birth (Lercher et al., 2002).

#### *4.8.1.3 Aircraft noise*

Community surveys have found that high percentages of people reported "headaches", "restless nights", and "being tense and edgy" in high aircraft noise areas (Kokokusha, 1973; Finke et al., 1974; Öhrström, 1989). An explicit link between aircraft noise and symptoms emerging in such studies raises the possibility of a bias towards over-reporting of symptoms (Barker and Tarnopolsky, 1978). Notably, a study around three Swiss airports (Grandjean et al., 1973), did not mention that it was related to aircraft noise and did not find any association between the level of exposure to aircraft noise and symptoms. In the West London Survey, "tinnitus", "burns, cuts and minor accidents", "ear problems" and "skin troubles" were all more common in areas of high noise exposure (Tarnopolsky, Watkins and Hand, 1980). Acute symptoms such as "depression", "irritability", "difficulty getting off to sleep", "night waking", "skin troubles", "swollen ankles" and "burns, cuts and minor accidents" were particularly common in high noise areas. However, apart from "ear problems" and "tinnitus", 20 out of 23 chronic symptoms were more common in low noise environments. Symptoms did not increase with increasing levels of noise. This is possibly related both to more social disadvantage and associated ill health among residents in low aircraft noise exposure areas and the possible unwillingness of chronically unhealthy individuals to move into potentially stressful high noise exposure areas. Nevertheless, it would not exclude an effect of noise in causing some acute psychological symptoms. As the majority of aircraft noise exposure is during the day, daytime exposure is likely to have greater effects than night-time exposure. Many of the effects of noise in industrial and teaching settings may be related primarily to disturbances in communication.

### 4.8.2 NOISE EXPOSURE AND MENTAL HOSPITAL ADMISSION RATES

Much of the concern with the possible effects of noise on mental health began with the study of admissions to psychiatric hospitals from noisy areas. Early studies found associations between the level of aircraft noise and psychiatric hospital admissions, both in London (Abey Wickrama et al., 1969) and Los Angeles (Meecham and Smith, 1977). These results have been criticized on methodological grounds (Chowns, 1970; Frerichs, Beeman and Coulson, 1980) and a replication study by Gattoni and Tarnopolsky (1973) failed to confirm these findings. Jenkins et al., (1979) found that age-standardized admission rates to a London psychiatric hospital over four years were higher as the level of noise of an area decreased, but lower noise areas were also central urban districts, where high admission rates would be expected. In a further extensive study of three hospitals (Jenkins, Tarnopolsky and Hand, 1981), high aircraft noise was associated with higher admission rates in two hospitals, but in all three of them, admission rates seemed to follow non-noise factors more closely; the effect of noise, if any, could only be moderating that of other causal variables but not overriding them. Kryter (1990), in a re-analysis of the data, found "a more consistently positive relation between level of exposure to aircraft noise and admissions rates". Undoubtedly, the route to hospital admission is influenced by many psychosocial variables that are more potent than exposure to noise. Therefore, whether or not noise causes psychiatric disorder is more suitably answered by studying a community sample.

### 4.8.3 NOISE EXPOSURE AND PSYCHIATRIC MORBIDITY IN THE COMMUNITY

In a community pilot study carried out in West London, Tarnopolsky et al. (1978) found no association between aircraft noise exposure and either GHQ scores (Goldberg, 1972) (dichotomized 4/5, low scorers/high scorers) or estimated psychiatric cases (Goldberg et al., 1970). This was the case even when exposure to road traffic noise was controlled, except in three subgroups: persons "aged 15–44 of high education" (41%, 14% $p<0.05$), "women aged 15–44" (30%, 13% n.s.), and those in "professional or managerial occupations". The authors expressed the guarded opinion that noise might have an effect in causing morbidity within certain vulnerable subgroups. In the subsequent West London Survey of Psychiatric Morbidity (Tarnopolsky, Morton-Williams and Barker, 1980), 5885 adults were randomly selected from within four aircraft noise zones, according to the Noise and Number Index. No overall relationship was found between aircraft noise and the prevalence of psychiatric morbidity either for GHQ scores or for estimated numbers of psychiatric cases, using various indices of noise exposure. However, there was an association between noise and psychiatric morbidity in two subgroups: "finished full-time education at age 19 years +", and "professionals". These two categories, which had a strong association with each other, were combined and then showed a significant association between noise and psychiatric morbidity ($X2 = 8.18$, df 3 $p<0.05$), but only for the proportion of high GHQ scorers. Tarnopolsky, Morton-Williams and Barker (1980) concluded that their results "show so far that noise per se in the community at large, does not seem to be a frequent, severe, pathogenic factor in causing mental illness but that it is associated with symptomatic response in selected subgroups of the population".

More recent studies have examined the effects of higher levels of military aircraft noise. Exposure to higher levels of military aircraft noise around the busy Kadena military airport in Japan was related in an exposure–effect association to depressiveness and nervousness measured by questionnaire using the Todai Health Index, based on the Cornell Medical Index (Ito et al., 1994; Hiramatsu et al., 1997). Mental health subscales included in this study measured depressiveness, nervousness, neurosis, and mental instability. Noise level was expressed as WECPNL (the power average of the maximum perceived noise exposure level in dB(A)) from 75–79, 80–84, 85–89, 90–94 and over 95). In unadjusted analyses, statistically significant differences were found in scores of depressiveness, nervousness and neurosis between the non-noise exposed control group and the pooled group exposed to 75–95 WECPNL. In multivariate analysis adjusting for age, sex, marital status, type of house and length of residence, noise exposure greater than 95 WECPNL was associated with higher scores on depressiveness and neurosis (Hiramatsu et al., 1997). Clear exposure–effect relationships were not found between scale scores and noise exposure, as expressed in five unit steps. However, using more broadly defined groups, an exposure–effect association was evident. This highlighted differences between the highest noise exposure group and lower exposure groups and indicated a threshold effect rather than a linear relationship – that mental health effects are more likely to be found at higher noise levels. In general, psychological rather than somatic symptoms were more related to noise in this study. Further analyses of the Japanese studies suggest that high levels of military aircraft noise may have effects on mental health. In a cross-sectional study of 5963 inhabitants around two air bases in Okinawa, those exposed to noise levels of $L_{dn}$ 70 or above had higher rates of "mental instability" and depressiveness (Hiramatsu et al., 2000). Those who were more annoyed showed a higher risk of mental or somatic symptoms. A further survey using similar methodology on 6486 respondents found exposure–effect associations between aircraft noise exposure, nervousness and mental health (Miyakita et al., 1998). These are important studies because of the opportunity to examine the effect of high noise-exposure levels and the probability that vulnerable people migrating out of noisy areas and thus biasing the sample was small.

The use of health services has also been taken as a measure of the relationship between noise and psychiatric disorder. Grandjean et al. (1973) reported that the proportion of the Swiss population taking drugs was higher in areas with high levels of aircraft noise and Knipschild and Oudshoorn (1977) found that the purchase of sleeping pills, antacids, sedatives and antihypertensive drugs all increased in a village newly exposed to aircraft noise, but not in a "control" village where the noise level remained unchanged. In both studies, there was also an association between the rate of contact with general practitioners and level of noise exposure. In the Heathrow study (Watkins, Tarnopolsky and Jenkins, 1981), various health care indicators were used – use of drugs, particularly psychiatric or self-prescribed, visits to the GP, attendance at hospital, and contact with various community services – but none of these showed any clear trend in relation to levels of noise. A recent study found that the use of sleeping tablets and sedatives was elevated with increasing night-time noise exposure, especially in the elderly (Passchier-Vermeer et al., 2002). This has been judged to be "sufficient" evidence of a noise effect (Health Council of the Netherlands, 2004).

### 4.8.4 AIRCRAFT NOISE EXPOSURE AND MENTAL HEALTH IN CHILDREN

Poustka, Eckermann and Schmeck (1992) studied the psychiatric and psychosomatic health of 1636 children aged 4–16 in two geographical regions that differed according to the noise made by jet fighters frequently exercising at low altitude. Psychological and neurological outcomes were not related to noise exposure. They found that associations between noise exposure and depression and anxiety could be demonstrated, but only beneath the threshold of clinical significance. These results are less convincing because the areas differed socioeconomically and the results were not adjusted for these factors and also because of lack of precision of the measures of noise exposure. However, in Munich, children living in areas exposed to high aircraft noise had lower levels of psychological well-being than children living in quieter environments (Evans, Hygge and Bullinger, 1995). The longitudinal data from around Munich showed that after the inauguration of the new airport, the newly noise-exposed communities demonstrated a significant decline in self-reported quality of life measured on the Kindl scale, after being exposed to the increased aircraft noise for 18 months (third wave of testing), compared with a control sample (Evans, Bullinger and Hygge, 1998). Impairment of "quality of life" is a less severe disturbance than impairment of mental health. Further studies have examined the effects of noise on child psychiatric disorders.

Chronic aircraft noise exposure was not associated with anxiety and depression (measured with psychometrically valid scales), after adjustment for socioeconomic factors, in the Schools Health and Environment Study around Heathrow Airport (Haines et al., 2001a). In a further larger study of children's health around Heathrow Airport – the West London Schools Study (Haines et al., 2001b) – an association was found between aircraft noise exposure level and increased hyperactivity scores on the hyperactivity subscale of the Strength and Difficulties Questionnaire (Goodman, 1997). These studies suggest that noise influences child mental health in terms of hyperactivity and that it may affect child stress responses and sense of well-being.

### 4.8.5 NEIGHBOURHOOD NOISE AND MENTAL HEALTH

Noise from neighbours is the commonest source of noise complaints to local authorities in the United Kingdom (Chartered Institute of Environmental Health, 1999). Noise which is continuous, apparently indefinite, of uncertain cause or source, emotive or frightening or apparently due to thoughtlessness or lack of consideration is most likely to elicit an adverse reaction (Grimwood, 1993). In the 1991 BRE survey, people most objected to barking dogs, banging doors, noise from radio, television, or hi-fi and human voices (Grimwood, 1993). In this survey, two types of emotional response to noise were observed: outwardly directed aggression, characterized by feelings of annoyance, aggravation, bitterness and anger towards the source of the noise, and a more emotional response of tension, anxiety and feelings of pressure. These responses are reminiscent of the distinction between internalizing and externalizing disorders. Whether noise from neighbours can induce psychiatric disorder has been little studied in community research, but this is an area that deserves further study (Stansfeld, Haines and Brown, 2000).

Undoubtedly, prolonged exposure to noise can be very upsetting, intrusive and interfering for sleep and everyday activities. In poorly built dwellings, especially apartments, even low intensity noises may be clearly audible through walls, floors, or ceilings (Raw and Oseland, 1991). In this situation, noise is destructive of privacy, especially for those living alone, and may be associated with perceptions of threat or increase a sense of isolation. This may be especially the case among people who are chronically anxious and likely to complain of sensitivity to noise; prolonged noise exposure may make them more anxious and unhappy. Often, this leads to arguments with neighbours, leading to a breakdown of neighbourly relationships and further isolation which may well in itself have a bad effect on mental health. Occasionally, this may be a sign of feelings of persecution associated with psychotic illness in which noise exposure is just an external trigger of an internally generated condition.

### 4.8.6 MECHANISMS FOR CAUSAL LINKS BETWEEN NOISE AND MENTAL HEALTH

What might the mechanism be for the effects of noise on mental health? One way to approach this is through the effects of noise on cognitive performance where the laboratory evidence of effects is fairly robust (Smith and Broadbent, 1992). Effects of noise on mental health might be expected because there is evidence that noise impairs other aspects of human functioning, such as performance (Loeb, 1986) and sleep, that are important in maintaining normal functioning, and that noise causes adverse emotional reactions such as annoyance. In general, it seems that noise exposure increases arousal, and decreases attention through distraction (Broadbent, 1953), increases the need for focusing attention to cut out irrelevant stimuli (Cohen and Spacapan, 1978), as well as altering choice of task strategy (Smith and Broadbent, 1981). Even relatively low levels of noise may have subtle ill effects, and in this respect, the state of the person at the time of performance may be as important as the noise itself (Broadbent, 1983). Individuals' perception of their degree of control over noise may also influence whether it impairs memory (Willner and Neiva, 1986) while perception of lack of control over environmental conditions may be an important mediator of health effects.

Additionally, noise may also affect social performance as: (1) a stressor causing unwanted aversive changes in affective state; (2) by masking speech and impairing communication; and (3) by distracting attention from relevant cues in the immediate social environment (Jones, Chapman and Auburn, 1981). It may be that people whose performance strategies are already limited for other reasons (for instance through high anxiety) and who are faced with multiple tasks may be more vulnerable to the masking and distracting effects of noise.

The mechanism for the effects of noise on health is generally conceptualized as fitting the stress–diathesis model, in which noise exposure increases arousal, and chronic exposure leads to chronic physiological change and subsequent health effects. It is not clear, however, whether this model is appropriate for mental health effects. A more sophisticated model (Biesiot, Pulles and Stewart, 1989; Passchier-Vermeer, 1993) incorporates the interaction between the person and their environment. In this model, the person readjusts their behaviour in noisy conditions to reduce exposure. An important addition is the inclusion of the appraisal of noise (in terms of danger, loss of quality, meaning of the noise, challenges for environmental control, etc.) and coping (the ability to alter behaviour to deal with the stressor). This model emphasizes that dealing with noise is an active not a passive process.

### 4.8.7 HABITUATION TO NOISE AND MENTAL HEALTH

It is likely that mental health effects arise from persistent exposure to noise over a long period of time. But do people habituate or adapt to noise over time? In some studies people do seem to adapt to noise and no longer notice noise that they are frequently exposed to. On the other hand, in some studies of annoyance there seems to be little evidence of adaptation (Cohen and Weinstein, 1981). It may be that, as in physiological studies, a failure of adaptation occurs if the stimulus is novel, salient or implies threat. The development of mental health symptoms implies a failure to habituate to noise, or at least to adapt to noise. In some studies control over noise or active coping with noise rather than passive emotion-focused coping is related to lower levels of symptom (van Kamp, 1990). Habituation has not been formally studied in relation to noise and mental health.

### 4.8.8 RISK GROUPS FOR MENTAL HEALTH EFFECTS FROM NOISE

One way to look at susceptibility to noise is to think about groups in the population who may be more susceptible to noise, for instance people with existing physical or mental illness tend to be more highly annoyed by noise and potentially could be vulnerable to mental health effects. Similarly, people with hearing impairment may be vulnerable to communication difficulties in noisy environments that could increase the risk of mental health symptoms. People who report that they are sensitive to noise tend to be more prone to noise annoyance and may be more at risk for common mental disorders (Stansfeld et al., 2002).

### 4.8.9 POPULATION GROUPS AT RISK FOR MENTAL HEALTH EFFECTS FROM NOISE

There is some evidence that children are more vulnerable to the mental health effects of noise than adults in terms of prematurity, low birth weight and through scoring higher on hyperactivity. There is no consistent evidence of age, social class, ethnic or gender differences in susceptibility to mental health effects from environmental noise.

### 4.8.10 NOISE SENSITIVITY

Noise sensitivity, based on attitudes to noise in general (Anderson, 1971; Stansfeld, 1992), is an intervening variable which explains much of the variance between exposure and individual annoyance responses (Weinstein, 1978; Langdon, Buller and



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Scholes, 1981; Fields, 1993). Individuals who are noise-sensitive are also likely to be sensitive to other aspects of the environment (Broadbent, 1972; Weinstein, 1978; Thomas and Jones, 1982; Stansfeld et al., 1985a). This raises the question as to whether noise-sensitive individuals are simply those who complain more about their environment. Certainly, there is an association between noise sensitivity and neuroticism (Thomas and Jones, 1982; Öhrström, Bjorkman and Rylander, 1988; Jelinkova, 1988; Belojevic and Jakovljevic, 1997; Smith, 2003), although it has not been found in all studies (Broadbent, 1972). On the other hand, Weinstein (1980) hypothesized that noise sensitivity is part of a critical/uncritical dimension, showing the same association as noise sensitivity to measures of noise, privacy, air pollution and neighbourhood reactions. He suggested that the most critical subjects, including noise-sensitive people are not uniformly negative about their environment, but more discriminating than the uncritical group, who comment uniformly on their environment.

Noise sensitivity has also been related to current psychiatric disorder (Bennett, 1945; Tarnopolsky, Morton-Williams and Barker, 1980; Iwata, 1984). Stansfeld et al. (1985) found that high noise sensitivity was particularly associated with phobic disorders and neurotic depression, measured by the Present State Examination (Wing, Cooper and Sartorius, 1974). Similar to this association with phobic symptoms, noise sensitivity has also been linked to a coping style based on avoidance, which may have adverse health consequences (Pulles, Biesiot and Stewart, 1988) and a tendency to report health complaints rather than take a more active coping approach to noise (Lercher and Kofler, 1996). Noise sensitivity may be partly secondary to psychiatric disorder: depressed patients followed over four months became less noise-sensitive as they recovered (Stansfeld, 1992). These "subjective" psychological measurements were complemented by an "objective" psychophysiological laboratory investigation of reactions to noise in a subsample of depressed patients. Noise-sensitive people tended to have higher levels of tonic physiological arousal, more phobic and defence/startle responses and slower habituation to noise (Stansfeld, 1992). Thus, noise-sensitive people attend more to noises, discriminate more between noises, find noises more threatening and out of their control, and adapt to noises more slowly than people who are less sensitive. Through its association with greater perception of environmental threat and its links with negative affectivity and physiological arousal, noise sensitivity may be an indicator of vulnerability to minor psychiatric disorder, although not necessarily psychiatric disorder caused by noise (Stansfeld, 1992).

In analysis of a subset of noise-sensitive women, compared to less sensitive women in the West London survey, there was no evidence that aircraft noise exposure predicted psychiatric disorder in the sensitive women (Stansfeld et al., 1985). In the Caerphilly study, noise sensitivity predicted psychological distress at follow-up after adjusting for baseline psychological distress, but did not interact with the noise level, suggesting that noise sensitivity does not specifically moderate the effect of noise on psychological distress (Stansfeld et al., 1993). However, in further analyses, a statistically significant association between road traffic noise exposure and psychological distress, measured by the General Health Questionnaire (GHQ), was found in noise-sensitive men, that was not found in men of low noise sensitivity (Stansfeld et al., 2002). In the original analyses, after adjusting for trait anxiety at baseline, the effect of noise sensitivity was no longer statistically significant. This suggests that much of the association between noise sensitivity and psychological distress may be accounted for by the confounding association with trait anxiety. Constitutionally anxious people may be both more aware of threatening aspects of their environment and more prone to future psychiatric disorder. It seems possible that these traits might be linked.

In a United Kingdom community study, associations were examined between noise exposure, noise sensitivity, subjective symptoms and sleep disturbance in a random sample of 543 adults (Smith, 2003). Perceived noise exposure was related to subjective health, but this association became non-significant after adjustment for negative affectivity. In a similar way, adjustment for negative affectivity eliminated the association between noise sensitivity and subjective health. Thus, it was suggested that noise sensitivity was merely a proxy measure of negative affectivity or neuroticism. However, although this means that noise sensitivity is not specific to noise, the more recent analyses suggest that high levels of trait anxiety or neuroticism may be an indicator of vulnerability to noise effects and could put people at risk of adverse psychological effects from noise, even if they do not increase the risk of physical ill health.

## 4.8.11 MENTAL HEALTH CONSEQUENCES OF INSOMNIA

Transient insomnia is usually accompanied by reports of daytime sleepiness and performance impairment the next day. Chronic insomnia is generally associated with poorer emotional and physical health. Several large-scale epidemiological studies of the general adult population have shown that between one third and one half of people who complain of chronic insomnia are also diagnosable with primary psychiatric disorders, mostly anxiety and mood disorders. Mellinger, Balter and Uhlenhuth (1985) found that 17% of adults reported "a lot" of trouble falling asleep or staying asleep over the past year; 47% of them had high levels of psychological distress, with symptom complexes suggestive of depression and anxiety disorders. In contrast, only 11% of individuals with no history of insomnia showed elevated levels of psychiatric symptoms. In a survey of almost 8000 individuals, Ford and Kamerow (1989) reported that 10% had suffered from significant insomnia for at least a two-week period during the previous six months; 40% of the insomniacs met criteria for psychiatric disorders, with the majority being anxiety disorders and depression; only 16% of those with no sleep complaints had psychiatric illness.

Breslau et al. (1996) found a strong correlation between lifetime prevalence of sleep problems and psychiatric disorders, with anxiety, depression, and substance abuse disorders being the most common. Similar results have been found by Vollrath, Wicki and Angst (1989), Chang et al. (1997) and Dryman and Eaton (1991). In a large-scale European population-based study (Ohayon and Roth, 2003), it was found that insomnia more often precedes rather than follows incident cases of mood disorders.

Insomniacs not only have higher rates of psychiatric disorders, but they also have increased rates of various kinds of psychological symptoms: patients with insomnia reported increased psychological stress and/or decreased ability to cope with stress according to surveys of the American (Roth and Ancoli-Israel, 1999) and Japanese (Kim et al., 2000) population. Almost 80% of insomniacs had a significant increase on one or more clinical scales on the Minnesota Multiphasic Personality Inventory (MMPI) (Kalogjera-Sackellares and Cartwright, 1997). Even people whose insomnia was due to identified medical factors showed elevation on the MMPI, suggesting a possible causal relationship or specific association between insomnia and psychiatric symptomatology. Compared to good sleepers, severe insomniacs reported more medical problems, had more GP office visits, were hospitalized twice as often and used more medication. Severe insomniacs had a higher rate of absenteeism, missing work twice as often as did good sleepers. They also had more problems at work (including decreased concentration, difficulty performing duties and more work-related accidents) (Leger et al., 2002).

## 4.8.12 INSOMNIA AS A MENTAL HEALTH SYMPTOM

Insomnia is a symptom of many psychiatric disorders, especially depression and anxiety. In studies of depressed patients compared to control subjects, there was prolonged latency to sleep, increased wakefulness during sleep, early morning wakening, decreased sleep efficiency and reduced total sleep time. There is also evidence that insomnia may be a risk factor for developing depression (Riemann, Berger and Voderholzer, 2001; Roberts, Roberts and Chen, 2002). This raises the question as to whether prolonged noise exposure leading to insomnia provokes the onset of depression in susceptible people? This seems theoretically possible, but there is little evidence to support it. In a longitudinal study of adolescents, it was the other way round – that depressive symptoms preceded the onset of insomnia (Patton et al, 2000). Delayed sleep latency in children has been linked to increased externalizing symptoms including aggressive behaviour, and impaired attention and social problems (Aronen et al., 2000). In this cross-sectional study, the direction of association was uncertain, but it seems most plausible that the sleep disturbance is a feature of the behavioural disturbance rather than a cause of it. Three criteria have been suggested for sleep disturbance to be environmentally determined: (1) the sleep problem is temporally associated with the introduction of a physically measurable stimulus or definable set of environmental circumstances; (2) the physical rather than the psychological properties of the environmental factors are the critical causative elements; and (3) removal of the responsible factors results in an immediate or gradual return to normal sleep and wakefulness (Kraenz et al., 2004). Most studies do not fulfil these criteria. In a German school-based study of 5–6-year-old children, sleep disturbance by noise, largely from road traffic, was reported "sometimes" in 10% by parents of children and 2% "often". Children's reports were slightly higher: "sometimes" in 12% and 3% "often" (Kraenz et al., 2004). Further longitudinal research is needed to ascertain whether noise-induced insomnia leads on to overt psychiatric disorder.

In summary, population as well as clinic-based studies have demonstrated a high rate of psychiatric morbidities in patients with chronic insomnia. It has traditionally been assumed that insomnia is secondary to the psychiatric disorders; however, it is possible that in some cases the insomnia preceded the psychiatric disorder.

## 4.8.13 DEPRESSIVE EPISODE AND ANXIETY DISORDERS

A mild depressive episode is diagnosed by clinical interview. The criteria for a mild depressive episode include two or more symptoms of depressed mood, loss of interest or fatigue lasting at least two weeks, with two or three symptoms such as reduced concentration, reduced self-esteem, ideas of guilt, pessimism about the future, suicidal ideas or acts, disturbed sleep, diminished appetite and social impairment, and fewer than four symptoms including lack of normal pleasure/interest, loss of normal emotional reactivity, waking =>2 hours early, loss of libido, diurnal variation in mood, diminished appetite, loss of =>5% body weight, psychomotor agitation or psychomotor retardation.

Anxiety disorders are similarly diagnosed by clinical interview. The criteria for "generalized anxiety disorders" include duration of at least six months of free-floating anxiety and autonomic overactivity.

### 4.8.14 ASSOCIATIONS BETWEEN INSOMNIA AND PSYCHIATRIC DISORDERS

At the present time, exposure–effect associations have not been established between parameters of sleep disturbance (number of behavioural awakenings, body movements or EEG awakenings) and the onset of depressive and anxiety disorders, although there is some evidence that insomnia is a risk factor for developing depression (Riemann, Berger and Voderholzer, 2001; Roberts, Roberts and Chen, 2002). A number of longitudinal prospective studies in different age groups have found associations between self-reports of insomnia and the subsequent onset of psychiatric disorder, in particular major depression. A selection of the most important studies and their findings are outlined in Table 4.3 below.

**Table 4.3 Insomnia as a predictor of psychiatric disorder**

| Study | Sample size | Sample | Follow-up interval | Depression measure | Results |
|---|---|---|---|---|---|
| Ford and Kamerow, 1989 | 7954 | Community sample | 1 year | Diagnostic interview schedule | Risk of developing new depression for insomnia on two occasions: [OR=39.8, 95% CI 19.8-80.0] |
| Breslau et al., 1996 | 1200 | 21–30 years members of health maintenance organization | 3 years | Diagnostic interview schedule | RR for new onset major depression associated with baseline insomnia [RR=4.0, 95% CI 1.5-5.6] |
| Chang et al., 1997 | 1053 | Male medical students | 34 years (median) | Clinical depression | RR for clinical depression for those who reported insomnia at medical school [RR= 2.0, 95% CI 1.2-3.3] |
| Roberts, Roberts and Chen, 2002 | 3136 | 11–17 years from managed care rosters | 1 year | Diagnostic interview schedule for children major depression module | Fully adjusted OR for insomnia in waves 1 and 2 for depression at follow-up [OR=1.92, 95% CI 1.30-2.82] |

### 4.8.15 CONCLUSIONS: ASSOCIATIONS BETWEEN NOISE AND PSYCHIATRIC DISORDERS

The effects of noise are strongest for those outcomes that, like annoyance, can be classified under "quality of life" rather than illness. What they lack in severity is made up for in numbers of people affected, as these responses are very widespread.

Current evidence does seem to suggest that environmental noise exposure, especially at higher levels, is related to mental health symptoms and possibly raised anxiety and consumption of sedative medication, but there is little evidence that it has more serious effects. Further research is needed on mental health effects at very high noise levels. Existing studies may be confounded either by prior selection of subjects out of (or into) noisy areas as a result of noise exposure, or by confounding between noise exposure, socioeconomic deprivation, and psychiatric disorder. It is also possible that people underestimate or minimize the effects of noise on health through optimism bias (Hatfield and Soames Job, 2001) and that this is particularly protective for mental health.

The evidence is not strong for the association between noise exposure and mental ill health. What evidence there is suggests that noise exposure may be responsible for psychological symptoms above 70 dB(A) $L_{eq}$. Almost all studies have only examined the effects of daytime noise on mental health, but it is possible that night-time noise, during sleep time, may have effects on mental health at lower levels than daytime noise.

The most powerful evidence of noise on mental health comes from studies of military aircraft noise. There is also some evidence that intense road traffic noise may lead to psychological symptoms. There is no evidence of any effects of railway noise on mental health.

## 4.9 THE SEVERITY OF SELF-REPORTED SLEEP DISTURBANCE

### 4.9.1 INTRODUCTION

In section 2.1.2 of Chapter 2 of this report, it is stated that sleep disturbance caused by noise may either be diagnosed (Environmental Sleep Disorder: ICSD 780-52-6) or self-reported. Although self-reported sleep disturbance is subjective by definition, its observed occurrence correlates with noise levels as well as with important diagnostic criteria for ICSD 780-52-6. It appears justified to consider self-reported sleep disturbance as an impairment of health, especially if indicated by representative population samples in social surveys. Furthermore, section 4.1 of Chapter 4 of this report gives a quantitative relationship between noise level $L_{night}$ and the percentage of population that reports a disturbed sleep of high, medium or low disturbance intensity.

But an open question concerns severity: even if night-time noise causes large percentages of the population to declare themselves as highly sleep-disturbed, this could nevertheless represent an almost negligible loss of health, if the mean severity of self-reported sleep disturbance were negligible in comparison with commonly accepted diseases. Attempts have been made to give an answer to this important question, using WHO's concept of disability weights (Murray et al., 1996) as a basis for severity comparisons.

### 4.9.2 AN ASSESSMENT OF DISABILITY WEIGHTS

A Swiss study (Müller-Wenk, 2002) aimed at determining a disability weight for sleep disturbance due to road traffic noise. For this purpose, a description of road-noise-related sleep disturbance was set up: essentially, this state of health was assumed to be present if a person indicated that, due to traffic noise, he or she, almost every night, had problems with falling asleep, with continuing sleep during the night or with early or non-restorative waking in the morning. In addition, a list was established with already available disability weights (Murray et al., 1996; Stouthard et al., 1997) for a selection of 28 diseases of various types, covering a range from very light severity to high severity (Müller-Wenk 2002:65–66). All 64 members of the medical staff of the Swiss Accident Insurance Institute (SUVA) were then asked in a written questionnaire to determine the hitherto unknown disability weight of sleep disturbance by interpolation, that is, by inserting sleep disturbance at the appropriate place between the presented 28 diseases that were sorted according to ascending disability weight. These participants were chosen because the physicians of the SUVA, besides being medical doctors, have a particularly high professional know-how in comparing the severity of different types of disability. Forty-two questionnaires were completed, of which 41 were usable.

From these questionnaires, an arithmetical mean of 0.055 of the disability weight for sleep disturbance could be calculated, with a 95% confidence limit of 0.039 at the low end and 0.071 at the high end. This result can be illustrated by mentioning diseases from the catalogues of Murray et al. (1996) or Stouthard et al. (1997) with the same disability weight: hence the disability weight of the road-noise-related sleep disturbance is roughly the same as the disability weight of "chronic hepatitis B infection without active viral replication", the latter having a mean disability weight of 0.06 and a 95% confidence interval from 0.034 to 0.087. The low-end estimate of 0.039 for sleep disturbance severity would correspond to the mean disability weight of "benign prostatic hypertrophy (symptomatic cases)", whilst the high estimate of 0.071 would correspond to the mean disability weight of "uncomplicated diabetes mellitus". The conclusion is that the mean disability weight of road-noise-related sleep disturbance is not smaller (= less severe) than the disability weight of health impairments commonly recognized as diseases, and there is a strong overlap amongst the probability distributions of these disability weights. On the basis of the chosen disability weight 0.055 for self-reported sleep disturbance, and taking into account the current traffic noise levels during the night in many European states, it is justified to consider noise-related sleep disturbance as a substantial loss of public health.

### 4.9.3 COMPARISON BETWEEN INSOMNIA AND SELF-REPORTED SLEEP DISTURBANCE

The original list of disability weights (Murray et al., 1996) did not contain any kind of non-normal sleep. In the meantime, WHO has published an extended list (Mathers et al., 2003, Annex Table 5a) containing a disability weight of 0.100 for insomnia (diagnostic code 307.42). This has opened a way to recheck the disability weight of 0.055 (Müller-Wenk, 2002), by asking a panel of medical professionals to compare, on the basis of disability weights, the mean severity of self-declared sleep disturbance due to road noise at night with the mean severity of insomnia. It may be debated whether it is more straightforward to compare two types of sleep anomalies with similar symptoms, or to compare self-declared sleep disturbance with various types of completely different diseases. But it makes sense anyway to use the comparison with insomnia as a second approach for determining the disability weight of self-reported sleep disturbance.

This severity comparison between different sleep anomalies was made in 2005 by structured oral interviews, executed by a medical staff member of the sleep clinic of Kantonsspital St. Gallen (Switzerland), with 14 GPs selected at random from all GPs who had admitted patients to the sleep clinic during the nine preceding months. These patients were mainly suffering from OSAS. The question was as follows:

> "Could you please give us your opinion on the relative severity of three different cases of insomnia:
>
> 1. (primary) insomnia, in our region usually called psychophysiological insomnia
> 2. Obstructive Sleep Apnoea Syndrome (OSAS)
> 3. traffic-noise-related sleep disturbance, that may occur with persons who are forced to sleep along through roads with nocturnal motor traffic.
>
> Your opinion should be based on the patients you have seen in your office lately, or on other persons of your social environment. When comparing the severity of the health impairment, the focus should be above all on the person's condition during the day after the sleep-disturbed night. The absolute value of the severity is less important for the current study than the relative severity amongst the three cases of insomnia. The opinion of the severity may be expressed on a linear scale from 0 (no impairment at all) to 10 (impairment almost unsupportable). On the scale from 0 to 10, you may give us your mean value of the severity, or you may give us a span from a low to a high for the severity."

All of the interviewed GPs gave their opinions, and the result is presented in Table 4.4.

**Table 4.4**
**Severity ratings (10 = almost insupportably disturbing, 0 = not in the least disturbing) by 14 GPs selected at random**

| | Primary insomnia | | | | OSAS (sleep apnoea) | | | | Sleep disturb.(noise) | | | | Ratio noise/ | Noise/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No | Max | Min | Mean | Rank | Max | Min | Mean | Rank | Max | Min | Mean | Rank | priminsomnia | OSAS |
| 10 | 6 | 4 | 5 | 3 | 8 | 6 | 7 | 1 | 8 | 6 | 7 | 1 | 1.40 | 1.00 |
| 11 | 5 | 3 | 4 | 3 | 9 | 7 | 8 | 1 | 8 | 4 | 6 | 2 | 1.50 | 0.75 |
| 12 | | | 5 | 3 | | | 10 | 1 | 7 | 8 | 7.5 | 2 | 1.50 | 0.75 |
| 13 | 2 | 3 | 2.5 | 2 | 4 | 5 | 4.5 | 1 | 1 | 2 | 1.5 | 3 | 0.60 | 0.33 |
| 14 | | | 3 | 2 | | | 6 | 1 | 1 | 2 | 1.5 | 3 | 0.50 | 0.25 |
| 15 | | | 8 | 2 | | | 9 | 1 | | | 6 | 3 | 0.75 | 0.67 |
| 16 | | | 8 | 1 | | | 7 | 2 | | | 4 | 3 | 0.50 | 0.57 |
| 17 | | | 5 | 1 | | | 5 | 1 | | | 3 | 3 | 0.60 | 0.60 |
| 18 | 2 | 3 | 2.5 | 2 | | | 6 | 1 | 1 | 2 | 1.5 | 3 | 0.60 | 0.25 |
| 19 | | | 8 | 1 | | | 3 | 2 | | | 2 | 3 | 0.25 | 0.67 |
| 20 | | | 6 | 2 | | | 7 | 1 | | | 4 | 3 | 0.67 | 0.57 |
| 21 | | | 7 | 2 | | | 8 | 1 | | | 0 | 3 | 0.00 | 0.00 |
| 22 | | | 4 | 3 | | | 5 | 2 | | | 6 | 1 | 1.50 | 1.20 |
| 23 | | | 4 | 3 | 6 | 7 | 6.5 | 2 | 8 | 9 | 8.5 | 1 | 2.13 | 1.31 |
| | | | | | | | | | | | | | | |
| Mean | | | 5.143 | 2.143 | | | 6.57 | 1.286 | | | 4.18 | 2.429 | 0.89 | 0.64 |
| Sigma | | | | | | | | | | | | | 0.60 | |
| Median | | | | | | | | | | | | | 0.63 | |
| Upper value 95% C.I. for mean | | | | | | | | | | | | | 1.20 | |
| Lower value 95% C.I. for mean | | | | | | | | | | | | | 0.58 | |

Clearly, the severity judgements vary widely between the participating GPs. Apart from the differences in personal judgement, this variation is certainly influenced by the mix of patients visiting a particular GP. For instance, GP number 15 could have encountered one or two very serious cases of OSAS, whilst his/her experience with noise-related sleep disturbance might refer to persons that were only moderately disturbed by night-time noise in their bedroom. On the other hand, number 22 could have had experience with persons suffering very much from sleep disturbance due to high traffic noise exposure, whilst his/her OSAS or primary insomnia patients happened to be light cases. One must accept that even GPs have a limited experience with the whole range of cases of each of the three types of insomnia, so that their opinion on the mean severity of noise-related sleep disturbance, compared to the mean severity of OSAS or insomnia, is influenced by the randomness of their patient mix.

Nevertheless, the table supports the following statements.

- With respect to severity, the majority of GPs rank noise-related sleep disturbance lower than insomnia and OSAS, while three of them put noise-related sleep disturbance in the first rank. Only one of the participants (number 21) considers noise-related sleep disturbance as a fully negligible disturbance.
- The severity ratio between noise-related sleep disturbance and insomnia varies between 0 and 2.1. Seven of the fourteen GPs indicate a severity ratio between 0.5 and 0.75, that is to say that half the participants are of the opinion that the severity of noise-related sleep disturbance amounts to 50–75% of the severity of insomnia.
- The mean of this severity ratio is 0.89, with a standard deviation (sigma) of 0.60. The confidence interval (CI) for the mean goes from 0.58 to 1.20. The median of the severity ratio is 0.63. The distribution is skewed to the right.

The severity ratio developed above can be used as a proportionality factor between the known disability weight for insomnia and the required disability weight for self-reported sleep disturbance. Bearing in mind that the already existing WHO disability weight for insomnia is 0.10, a best guess for the mean disability weight for self-reported sleep disturbance due to road traffic noise at night is therefore 0.089, with a CI from 0.058 to 0.12.

### 4.9.4 CONCLUSIONS

According to the two groups of interviewed medical professionals, persons that declare themselves to be chronically deprived of normal sleep by road traffic noise have a health state whose mean disability weight is comparable to "chronic hepatitis B infection without active viral replication" or higher. Irrespective of the question whether self-reported sleep disturbance is formally recognized as a disease or not, its severity is comparable to commonly accepted diseases.

The best estimate for a mean disability weight for self-reported sleep disturbance due to road traffic noise was 0.055 (CI: 0.039; 0.071) according to Müller-Wenk (2002), whilst our recheck based on a comparison with insomnia resulted in a disability weight of 0.09 (CI: 0.06; 0.12). The higher disability weight according to the second approach might be caused by the fact that in this second approach, there was a stronger focus on "the person's condition during the day after the sleep-disturbed night".

The above figures compare reasonably with a study published by van Kempen (1998), cited in Knol and Staatsen (2005:46), where a severity weight of 0.10 for severe sleep disturbance was found, based on the judgement of 13 medical experts according to the protocol of Stouthard et al. (1997).

In conclusion, a mean disability weight of 0.07 is proposed for self-reported sleep disturbance due to road noise or similar ambient noise. This disability weight can be used in connection with the equations of section 4.1 of this chapter for highly sleep-disturbed persons.

## 4.10 DISCUSSION: CAN CHRONIC SHORT-TERM EFFECTS CAUSE LONG-TERM EFFECTS ON HEALTH?

EEG modifications, cardiovascular responses, body movements and awakenings due to noise occur within a few seconds after the stimulus. In addition to the instantaneous effects related to single events, large field studies on aircraft (Passchier-Vermeer et al., 2002) and road traffic noise exposure during night-time (Griefahn et al., 2000; Passchier-Vermeer et al., 2004) show that also sleep latency and average motility during the sleep period increased monotonously as a function of the noise exposure level. The increase in average motility was substantially higher than would be expected on the basis of the instantaneous extra motility at the times of the noise events (Passchier-Vermeer et al., 2002) suggesting persistent arousal during the sleep related to aircraft noise. Furthermore, an international field study (Jurriëns et al., 1983) found slightly reduced REM sleep, increased time being awake according to the EEG, increased average heart rate, and reduced performance on a reaction time test in people when exposed during the night to higher road traffic noise levels.

The relationship between instantaneous effects and more global modifications of one night sleep, as well as chronic changes, is not simple, as illustrated by the findings concerning motility. An increase in average motility that is substantially higher than would be expected on the basis of the instantaneous extra motility at the times of the noise events (Passchier-Vermeer et al., 2002) suggests a persistent arousal during sleep related in a dose-dependent way to the aircraft noise.

Since EEG arousal and instantaneous motility are correlated, this finding suggests that also the number of (micro-)arousals may increase during noise exposure more than by the sum of the instantaneous (micro-)arousals that occur contingent upon a noise event.

For overall motility during sleep, clear indications have been found of associations with further effects, although the causal direction is not in all cases clear. Mean (onset of) motility during sleep is associated with the following variables based on questionnaires and diaries (Passchier-Vermeer et al., 2002):

- frequency of conscious awakening during the sleep period: the increase is 0.8 conscious;
- awakenings per night, if motility increases from low to high;
- frequency of awakening remembered next morning: the increase is 0.5 remembered;
- awakenings per night, if motility increases from low to high;
- long-term frequency of awakening attributed to specific noise sources assessed with a questionnaire;
- sleep quality reported in a morning diary;
- long-term sleep quality assessed with a questionnaire;

- number of sleep complaints assessed with a questionnaire;
- number of general health complaints assessed with a questionnaire.

The associations of mean motility with these variables are stronger than the corresponding associations of mean onset of motility.

For evaluating the adverseness of the instantaneous effects, it is important to consider whether they bring the body into a more persistent state of higher arousal or not, although this is not the only criterion. Those effects which are progressively disappearing with the repetition of the stimulus may be less harmful than those which do persist over long exposure time, provided that the suppression of the effects do not require costs in another form. For example, short-term cardiovascular effects that appear not to habituate could lead to permanent cardiovascular system impairment (Carter, 1996, 1998).

The relations presented for motility and conscious awakening imply that motility is sensitive to noise and has a relatively low threshold, while conscious awakening, the strongest instantaneous interference of noise with sleep, has the highest threshold of the instantaneous effects considered.

In one of the most sophisticated field studies (Passchier-Vermeer et al., 2002), increased probability of instantaneous motility was found for events with a maximum sound level $L_{Amax}$ > 32 dB(A), while in a meta-analysis conscious awakening was found for events with $L_{Amax}$ > 42 dB(A) (Passchier-Vermeer, 2003a). Above their threshold, these effects were found to increase monotonously as a function of the maximum sound level during a noise event (aircraft noise). It is important to note that in another recent sophisticated field study (Basner et al., 2004), the threshold found for EEG awakening was $L_{Amax}$ = 35 dB(A), that is, only a little higher than the 32 dB(A) found for noise-induced awakenings. This strengthens the evidence that noise starts to induce arousals at $L_{Amax}$ values in the range 30–35 dB(A). Given the night-time noise levels to which people are exposed, these results imply that instantaneous effects are common. Although most studies concerned aircraft noise, the instantaneous effects can be assumed to occur at similar levels for different types of transportation.

The above observations can be used as a basis for setting limits with respect to night-time transportation noise. For transparency, it is useful to distinguish two steps in choosing actual limits: the first step is the derivation of a health-based limit; the second step is the derivation of an actual limit that takes into account the health-based limit as well as feasibility arguments. Here the concern is with the first step.

When deriving a health-based limit, two points need to be considered: the dose-dependent effects of a single noise event, and the number of events. With respect to the dose-dependent effects of a single event, adverse effects can be distinguished from effects that by themselves need not be adverse but can contribute to an adverse state. It is proposed to classify conscious awakenings as an adverse effect. Conscious awakenings have been estimated to occur at a baseline rate of 1.8 awakening per night. A substantial increment of conscious awakenings over this baseline is thought to be adverse. Since, in general, falling asleep after conscious awakening takes some time, and this latency is longer after noise-induced conscious awakening that will often also induce an emotional reaction (anger, fear), it will also reduce the time asleep and may affect mood and functioning next day. Although additional, more sophisticated analyses could be performed to refine this estimate, we propose $L_{Amax}$

= 42 dB(A) is proposed as the currently best estimate of the threshold for conscious awakening by transportation noise. This would mean that the no observed effect level ($NOEL_{Amax}$) for transportation noise events is at most 42 dB(A).The most sensitive instantaneous effect that has been studied extensively in field studies is motility. A single interval with (onset of) noise-induced motility by itself cannot be considered to be adverse.

However, noise-induced motility is a sign of arousal, and frequent (micro-)arousal and accompanying sleep fragmentation can affect mood and functioning next day and lead to a lower rating of the sleep quality. Therefore, motility is relevant for adverse health effects, but more than a few intervals with noise-induced motility are needed for inducing such effects. Although additional, more sophisticated analyses could be performed to refine this estimate, we propose $L_{Amax}$ = 32 dB(A) as the currently best estimate of the threshold for motility induced by transportation noise. The threshold found for EEG awakening was $L_{Amax}$ = 35 dB(A), that is, only a little higher than the 32 dB(A) found for noise-induced awakenings. This would mean that the $NOEL_{Amax}$ for transportation noise events is most likely at most 32 dB(A), and definitely not higher than 35 dB(A). It is important to note that the above given $NOEL_{Amax}$ ~ 32 dB(A) and $NOEL_{Amax}$ ~ 42 dB(A) are indoor levels, in the sleeping room. Although events below 32 dB(A) are audible, and, hence, further research may show more sensitive effects than motility, on the basis of the present available evidence we propose to assume that $NOEL_{Amax}$ = 32 dB(A) and set a health-based night-time noise limit that is tolerant for transportation noise events with $L_{Amax}$ ~ 32 dB(A). On the other hand, since adverse health effects need to be prevented by health-based limits and even though vulnerable groups may require lower limits, on the basis of the present available evidence we propose to assume that $NOAEL_{Amax}$ = 42 dB(A) and set a health-based night-time noise limit that does not tolerate transportation noise events with $L_{Amax}$ > 42 dB(A).

On the basis of the above proposal, it would be possible to derive a night-time noise guideline value in terms of $L_{night}$. Such a guideline value would indicate the level below which no short-term effects are to be expected that would lead to temporary reduced health or chronic disease. Such a guideline value needs to be compared with guideline values derived directly with a view to preventing temporary reduced health and chronic diseases. In particular, for self-reported sleep disturbance, which is an expression of reduced well-being and may be an indication of effects that could contribute to cardiovascular disease, exposure–effect relationships have been derived on the basis of an extensive set of original data from studies from various countries (Miedema, Passchier-Vermeer and Vos, 2003; Miedema, 2004). The percentage of people reporting high noise-induced sleep disturbance (%HS) levels off at 45 dB(A) but at a non-zero effect level. The remaining effect may be caused by events not incorporated in the exposure assessment and it appears that if all noise contributions would be incorporated in the exposure metric, high noise-induced sleep disturbance would vanish between 40 dB(A) and 45 dB(A), say at 42 dB(A). Since values found for other temporary reduced health effects or chronic diseases, in particular cardiovascular diseases, will be higher, and considering self-reported sleep disturbance as an adverse effect, this would suggest $L_{night}$ = 42 dB(A) as the NOAEL to be compared with the value derived from the short-term effects. Note that this is an outdoor level, which would, assuming partly opened windows and an actual insulation of 15 dB(A), correspond to an indoor equivalent night-time sound level of 27 dB(A). The above discussion is based on motility, EEG awakenings, and conscious awakening. In addition, EEG micro-/minor arousals, and autonomic reactions have been discussed above.

Furthermore, there are potential instantaneous effects, such as effects on memory consolidation or restoration of the immune system, for which the information on a possible relation with noise exposure is so limited that they were not considered here. In order to acquire more insight into these effects, more field research is needed. Field research is needed because earlier studies have shown that estimates of effects on the basis of laboratory studies are much higher than estimates from field studies. Methodological differences between the different approaches certainly cannot be the only possible explanation. Research allowing the introduction of some specific but light laboratory technique into the sleeper's own bedroom, should be encouraged, as, for example, used in the Swiss Noise Study 2000 (Brink, Müller, and Schierz, 2006). The key to better insight into effects of night-time noise, leading to mechanistic models describing the relationships between noise exposure, instantaneous effects, effects at the level of a 24-hour period and chronic effects, appears to be epidemiological studies at home with well-designed instrumentation.

The relationships between noise exposure, instantaneous effects, effects at the level of a single 24-hour period and chronic effects is complex because the effects at a smaller time scale do not simply add up to effects at a larger time scale. For example, the noise-related increase in night-time average motility was substantially higher than would be expected on the basis of the instantaneous extra motility at the times of the noise events (Passchier-Vermeer et al., 2002), suggesting persistent arousal during sleep related to aircraft noise. It is likely that such shifts in the basic state are more important for the development of chronic effects than the instantaneous effects per se. A further complication is that some effects habituate. Habituation in some effect parameters can occur in a few days or weeks, but the habituation is not always complete. The measured modifications of the cardiovascular functions remain unchanged over long periods of exposure time (Muzet and Ehrhart, 1980; Vallet et al., 1983). Most striking is that none of the cardiovascular responses show habituation to noise after a prolonged exposure, while subjective habituation occurs within a few days. It appears plausible that, in particular non-habituating effects lead to the development of chronic effects, but also the disappearance of effects with continuing exposure may come at a cost associated with suppressing the effects. A third complication is that daytime noise exposure may contribute to the effects found in relation to night-time noise. Large epidemiological studies are needed that compare populations exposed to similar daytime noise and differ in their night-time noise exposure only. A specific challenge for mechanistic models on the effects of noise on sleep is the identification of factors that make subjects vulnerable to night-time noise. The following groups may be hypothesized to be more vulnerable to noise during sleep: old people, ill people, people with chronic insomnia, shift workers and people resting during daytime, people with a tendency to depression, light sleepers, pregnant women, people with high anxiety and high stress levels. Furthermore, children need attention because of their relatively high exposure during sleep, and because they are in a phase of neurocognitive development for which undisturbed sleep may be particularly important.

# CHAPTER 5

# GUIDELINES AND RECOMMENDATIONS

## 5.1 ASSESSMENT

In Chapter 1 the need for a guideline document for night-time exposure to noise was defended on the basis of the lack of existing guidance, the signs that a substantial part of the population could be exposed to levels of noise that might risk their health and well-being and the EU activities that compel the public and authorities to take notice when noise maps showing $L_{night}$ levels are made public.

Where sufficient direct evidence concerning the effects of night-time noise on health could not be collected, indirect evidence was looked at: the effects of noise on sleep (quality) and the relations between sleep and health.

In Chapter 2 the evidence was presented that sleep is a biological necessity and disturbed sleep is associated with a number of health outcomes. Studies of sleep disturbance in children and in shift workers clearly show the adverse effects. Unravelling the relations between sleep and health (Fig. 2.1) shows that sleep is an essential feature of the organism, so that simple direct relations can hardly be expected.

In Chapter 3 it was shown beyond doubt that noise disturbs sleep through a number of direct and indirect pathways. Even at very low levels physiological reactions (heart rate, body movement and arousals) can be reliably measured. It was also shown that awakening reactions are relatively rare, occurring at a much higher level.

Chapter 4 summarized the known evidence for the direct effects of night-time noise on health. The working group agreed that there is sufficient evidence that night noise is related to self-reported sleep disturbance, use of pharmaceuticals, self-reported health problems and insomnia-like symptoms. These effects can lead to a considerable burden of disease in the population. For other effects (hypertension, myocardial infarctions, depression and others), limited evidence was found: although the studies were few or not conclusive, a biologically plausible pathway could be constructed from the evidence.

An example of a health effect with limited evidence is myocardial infarction. Although evidence for increased risk of myocardial infarction related to $L_{day}$ is sufficient according to an updated meta-analysis, the evidence in relation to $L_{night,outside}$ was considered limited. This is because $L_{night,outside}$ is a relatively new exposure indicator, and few field studies have focused on night noise when considering cardiovascular outcomes. Nevertheless, there is evidence from animal and human studies supporting a hypothesis that night noise exposure might be more strongly associated with cardiovascular effects than daytime exposure, highlighting the need for future epidemiological studies on this topic.

The review of available evidence leads to the following conclusions.

- Sleep is a biological necessity and disturbed sleep is associated with a number of health outcomes.

- There is sufficient evidence for biological effects of noise during sleep: increase in heart rate, arousals, sleep stage changes and awakening.
- There is sufficient evidence that night noise exposure causes self-reported sleep disturbance, increase in medicine use, increase in body movements and (environmental) insomnia.
- While noise-induced sleep disturbance is viewed as a health problem in itself (environmental insomnia), it also leads to further consequences for health and well-being.
- There is limited evidence that disturbed sleep causes fatigue, accidents and reduced performance.
- There is limited evidence that noise at night causes hormone level changes and clinical conditions such as cardiovascular illness, depression and other mental illness. It should be stressed that a plausible biological model is available with sufficient evidence for the elements of the causal chain.

In the next section threshold levels are presented for the effects, where these can be derived.

## 5.2 THRESHOLDS FOR OBSERVED EFFECTS

The NOAEL is a concept from toxicology, and is defined as the greatest concentration which causes no detectable adverse alteration of morphology, functional capacity, growth, development or lifespan of the target organism. For the topic of night-time noise (where the adversity of effects is not always clear) this concept is less useful. Instead, the observed effect thresholds are provided: the level above which an effect starts to occur or shows itself to be dependent on the dose. This can also be an adverse effect (such as myocardial infarcts) or a potentially dangerous increase in a naturally occurring effect such as motility.

Threshold levels are important milestones in the process of evaluating the health consequences of environmental exposure. The threshold levels also delimit the study area, which may lead to a better insight into overall consequences. In Tables 5.1 and 5.2 all effects are summarized for which sufficient or limited evidence exists (see Table 1.2 in Chapter 1 for a definition). For the effects with sufficient evidence the threshold levels are usually well known, and for some the dose-effect relations over a range of exposures could also be established.

## 5.3 RELATIONS WITH $L_{NIGHT,OUTSIDE}$

Over the next few years, the END will require that night exposures are reported in $L_{night,outside}$. It is therefore interesting to look into the relation between $L_{night,outside}$ and the effects from night-time noise. The relation between the effects listed in Tables 5.1 and 5.2 and $L_{night,outside}$ is, however, not straightforward. Short-term effects are mainly related to maximum levels per event inside the bedroom: $L_{Amax,inside}$. In order to express the (expected) effects in relation to the single EU indicator, some calculation needs to be done.

**Table 5.1**
**Summary of effects and threshold levels for effects where sufficient evidence is available**

| Effect | | Indicator | Threshold, dB | Reference (chapter, section) |
|---|---|---|---|---|
| Biological effects | Change in cardiovascular activity | * | * | 3.1.5 |
| | EEG awakening | $L_{Amax}$, inside | 35 | 4.10 |
| | Motility, onset of motility | $L_{Amax}$, inside | 32 | 3.1.8, dose–effect relation for aircraft |
| | Changes in duration of various stages of sleep, in sleep structure and fragmentation of sleep | $L_{Amax}$, inside | 35 | 3.1 |
| Sleep quality | Waking up in the night and/ or too early in the morning | $L_{Amax}$, inside | 42 | 3.1.7, dose–effect relation for aircraft |
| | Prolongation of the sleep inception period, difficulty getting to sleep | * | * | 3.1 |
| | Sleep fragmentation, reduced sleeping time | * | * | 3.1 |
| | Increased average motility when sleeping | $L_{night}$, outside | 42 | 3.2, dose–effect relation for aircraft |
| Well-being | Self-reported sleep disturbance | $L_{night}$, outside | 42 | 4.2, dose–effect relation for aircraft/road/rail |
| | Use of somnifacient drugs and sedatives | $L_{night}$, outside | 40 | 4.5.8 |
| Medical conditions | Environmental insomnia** | $L_{night}$, outside | 42 | 3.1; 4.1; 4.2 |

* *Although the effect has been shown to occur or a plausible biological pathway could be constructed, indicators or threshold levels could not be determined.*

** *Note that "environmental insomnia" is the result of diagnosis by a medical professional whilst "self-reported sleep disturbance" is essentially the same, but reported in the context of a social survey. Number of questions and exact wording may differ.*

**Table 5.2**
**Summary of effects and threshold levels for effects where limited evidence is available+**

| Effect | | Indicator | Estimated, threshold dB | Reference (chapter, section) |
|---|---|---|---|---|
| Biological effects | Changes in (stress) hormone levels | * | * | 2.5 |
| | Drowsiness/tiredness during the day and evening | * | * | 2.2.3 |
| | Increased daytime irritability | * | * | 2.2.3 |
| Well-being | Impaired social contacts | * | * | 2.2.3 |
| | Complaints | $L_{night,outside}$ | 35 | 4.3 |
| | Impaired cognitive performance | * | * | 2.2.3 |
| | Insomnia | * | * | 4.6 |
| | Hypertension | $L_{night,outside}$ | 50 | 2.2.3; 4.5.6 |
| | Obesity | * | * | 2.2.3 |
| | Depression (in women) | * | * | 4.8 |
| | Myocardial infarction | $L_{night,outside}$ | 50 | 4.5.15 |
| | Reduction in life expectancy (premature mortality) | * | * | 2.2.3; 2.5 |
| | Psychiatric disorders | $L_{night,outside}$ | 60 | 4.8.15 |
| | (Occupational) accidents | * | * | 2.2.3; 2.4 |

+ *Note that as the evidence for the effects in this table is limited, the threshold levels also have a limited weight. In general they are based on expert judgement of the evidence.*

* *Although the effect has been shown to occur or a plausible biological pathway could be constructed, indicators or threshold levels could not be determined.*

The calculation for the total number of effects from reaction data on events (arousals, body movements and awakenings) needs a number of assumptions. The first that needs to be made is independence: although there is evidence (Brink, Müller and Schierz, 2006) that the order of events of different loudness strongly influences the reactions, the calculation is nearly impossible to carry out if this is taken into consideration.

Secondly, the reactions per event are known in relation to levels at the ear of the sleeper, so an assumption for an average insulation value must be made. In this report a value of 21 dB (see Chapter 1, sections 1.3.4 and 1.3.5) has been selected. This value is, however, subject to national and cultural differences. One thing that stands out is the desire of a large part of the population to sleep with windows (slightly) open. The relatively low value of 21 dB already takes this into account. If noise levels increase, people do indeed close their windows, but obviously reluctantly, as then complaints about bad air increase and sleep disturbance remains high. This was already pointed out in the WHO guidelines on community noise (WHO, 1999).

From source to source the number of separate events varies considerably. Road traffic noise is characterized by relatively low levels per event and high numbers, while air and rail traffic are characterized by high levels per event and low numbers. For two typical situations estimates are made and presented in graphical form. The first is an average urban road (600 motor vehicles per night, which corresponds roughly to a 24-hour use of 8000 motor vehicles, or 3 million per year, the lower boundary the END sets) and the second case is for an average situation of air traffic exposure (8 flights per night, nearly 3000 per year).

Fig. 5.1 shows how effects increase with an increase of $L_{night,outside}$ values for the typical road traffic situation (urban road ). A large number of events lead to high levels of awakening once the threshold of $L_{Amax,inside}$ is exceeded. To illustrate this in practical terms: values over 60 dB $L_{night,outside}$ occur at less then 5 metres from the centre of the road.

In Fig. 5.2 the same graph is presented for the typical airport situation. Due to a lower number of events there are fewer awakenings than in the road traffic case (Fig. 5.1), but the same or more health effects.

In these examples the worst case figures can be factors higher: the maximum number of awakenings for an $L_{night,outside}$ of 60–65 dB is around 300 per year.

A recent study suggests that high background levels (from motorways) with low numbers of separate events can cause high levels of average motility (Passchier-Vermeer, to be published). In Table 5.3 the full details are summarized.

## 5.4 DEALING WITH SITUATIONS EXCEEDING THE THRESHOLDS

Noise exposure data demonstrate that a large part of the population is over the no-effect levels. It is expected that this will extend into the future for quite some time. This means that circumstances may require that a risk assessment must be made. It is then recommended to apply the method laid out in Chapter 1, using the values given in Tables 5.1 and 5.2 and the dose–effect relations given in Chapter 4.

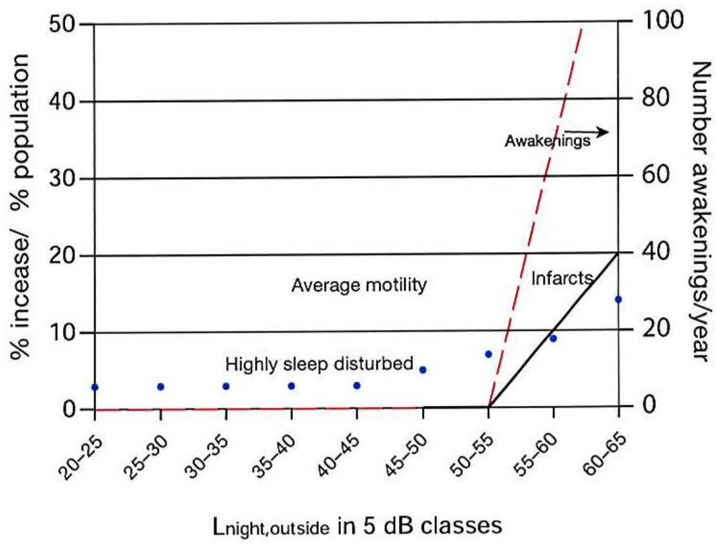
Typical actions requiring risk assessment are:

- new infrastructure projects (if an environmental impact statement is required)
- improvement programmes

- policy evaluation
- national or international setting of limit values.

In the EU *Position Paper* (European Commission, 2002a) an overview of national night-time noise regulations can be found.

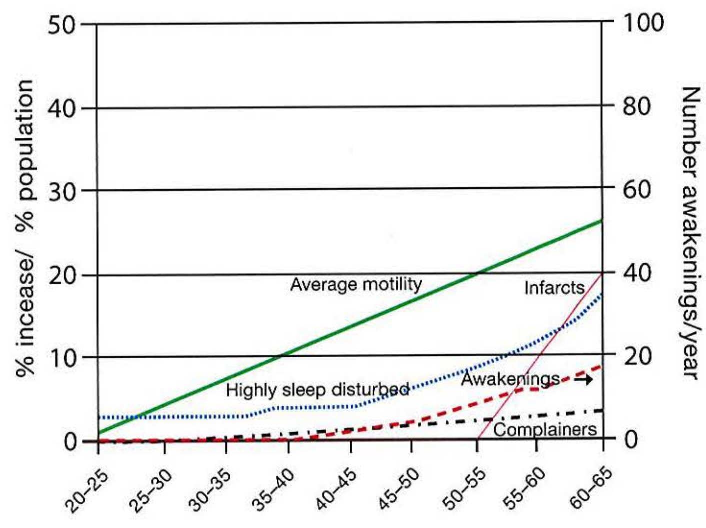
**Fig. 5.1**
**Effects of road traffic noise at night***




*Source: European Commission, 2002 a*

* *Average motility and infarcts are expressed in percent increase (compared to baseline number); the number of highly sleep disturbed people is expressed as a percent of the population; awakenings are expressed in number of additional awakenings per year.*

**Fig. 5.2**
**Effects of aircraft noise at night***




*Source: European Commission, 2002 a*

* *Average motility and infarcts are expressed in percent increase (compared to baseline number); the number of highly sleep disturbed people is expressed as percent of the population; complainers are expressed as a percent of the neighbourhood population; awakenings are expressed in number of additional awakenings per year.*

**Table 5.3**
**Effects (yearly, additional with respect to the normal except odd ratio) 0=below threshold, +=increase)**

| $L_{night, outside}$ | Arousals | | Body movements related to single exposures (15 sec intervals) | | Average body movements (without single exposures) | Awakenings | | % sleep disturbed (% highly sleep disturbed) | | | Myocardial infarcts |
|---|---|---|---|---|---|---|---|---|---|---|---|
| UNIT | number | number air | number average traffic | number average urban road | number | number average air traffic | number average urban road | % of exposed air | road | rail | odd ratio |
| NORMAL | Children 2 555 | Adults 3 650 | 21 000 | | 21 000 | 600 | | 0 | | | 1 |
| 20–25 | 0 | 0 | 0 | 0 | 200 | 0 | 0 | 0 | 0 | 0 | 1 |
| 25–30 | 0 | 0 | 7 | 0 | 875 | 0 | 0 | <3 | <3 | <2 | 1 |
| 30–35 | + | + | 22 | 0 | 1 547 | 0 | 0 | <3 | <3 | <2 | 1 |
| 35–40 | + | + | 37 | 0 | 2 220 | 0 | 0 | 4 | 3 | 2 | 1 |
| 40–45 | + | + | 58 | 243 | 2 900 | 2 | 0 | 4 | 3 | 2 | 1 |
| 45–50 | + | + | 85 | 635 | 3 600 | 5 | 0 | 6 | 5 | 2 | 1 |
| 50–55 | + | + | 111 | 1 145 | 4 200 | 9 | 0 | 9 | 7 | 3 | 1 |
| 55–60 | + | + | 145 | 1 770 | 4 900 | 12 | 54 | 12 | 9 | 4 | 1.1 |
| 60–65 | + | + | 180 | 2 520 | 5 500 | 17 | 155 | 17 | 14 | 6 | 1.2 |

*Source: European Commission, 2002 a*

## 5.5 PROTECTION MEASURES AND CONTROL

What is the best strategy to reduce sleep disturbance? The first thought should always be to reduce the impact, either by reducing the number of events or by reducing the sound levels, or both. For some effects reducing the number of events may seem to be more effective (although that depends on the exact composition). Other effects are reduced by lowering overall noise level by either the number of events, the levels per event or by any combination.

In combination with other measures, sound insulation of bedroom windows is an option, but care must be taken to avoid negative impact on inside air quality. Even then, many people may want to sleep with their windows open, thereby making the insulation ineffective. Although good instruction may go some way to helping to overcome this, it is still a matter well worth taking into account. In warmer climates, in particular, insulation is not a serious option for residential purposes and excessive exposure must be avoided either by removing the people exposed or removing the source if source-related measures fail.

Although air conditioning of houses (or just bedrooms) is not commonplace in the EU, there are indications that its use is increasing, especially in the warmer parts of the Region. Although this still leaves the possibility that people may sleep with their windows open outside the summer season, it is something to consider when discussing measures.

Exposed areas could be a good choice for uses such as offices, where there will be no people at night, or where it is a physical impossibility to sleep with the windows open (fully air-conditioned buildings, for example hotels and sometimes hospitals).

A simple measure is the orientation of noise-sensitive rooms on the quiet side of the dwelling (this applies to road and rail traffic noise).

Zoning is an instrument that may assist planning authorities in keeping noise-sensitive land uses away from noisy areas. In the densely populated areas of the EU this solution must often compete, however, with other planning requirements or a simple lack of suitable space.

## 5.6 RECOMMENDATIONS FOR HEALTH PROTECTION

Sleep is an essential part of healthy life and is recognized as a fundamental right under the European Convention on Human Rights[1](European Court of Human Rights, 2003). Based on the systematic review of evidence produced by epidemiological and experimental studies, the relationship between night noise exposure and health effects can be summarized as below. (Table 5.4)

**Table 5.4**
**Effects of different levels of night noise on the population's health[2]**

| Average night noise level over a year $L_{night,outside}$ | Health effects observed in the population |
|---|---|
| Up to 30 dB | Although individual sensitivities and circumstances may differ, it appears that up to this level no substantial biological effects are observed. $L_{night,outside}$ of 30 dB is equivalent to the NOEL for night noise. |
| 30 to 40 dB | A number of effects on sleep are observed from this range: body movements, awakening, self-reported sleep disturbance, arousals. The intensity of the effect depends on the nature of the source and the number of events. Vulnerable groups (for example children, the chronically ill and the elderly) are more susceptible. However, even in the worst cases the effects seem modest. $L_{night,outside}$ of 40 dB is equivalent to the LOAEL for night noise. |
| 40 to 55 dB | Adverse health effects are observed among the exposed population. Many people have to adapt their lives to cope with the noise at night. Vulnerable groups are more severely affected. |
| Above 55 dB | The situation is considered increasingly dangerous for public health. Adverse health effects occur frequently, a sizeable proportion of the population is highly annoyed and sleep-disturbed. There is evidence that the risk of cardiovascular disease increases. |

[1] "Article 8:1. Everyone has the right to respect for his private and family life, his home and his correspondence." Although in the case against the United Kingdom the Court ruled that the United Kingdom Government was not guilty of the charges, the right to undisturbed sleep was recognized (the Court's consideration 96).

[2] $L_{night,outside}$ in Table 5.4 and 5.5 is the night-time noise indicator ($L_{night}$) of Directive 2002/49/EC of 25 June 2002: the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year; in which: the night is eight hours (usually 23.00 – 07.00 local time), a year is a relevant year as regards the emission of sound and an average year as regards the meteorological circumstances, the incident sound is considered, the assessment point is the same as for $L_{den}$. See *Official Journal of the European Communities*, 18.7.2002, for more details.

Below the level of 30 dB $L_{night,outside}$, no effects on sleep are observed except for a slight increase in the frequency of body movements during sleep due to night noise. There is no sufficient evidence that the biological effects observed at the level below 40 dB $L_{night,outside}$ are harmful to health. However, adverse health effects are observed at the level above 40 dB$L_{night,outside}$, such as self-reported sleep disturbance, environmental insomnia, and increased use of somnifacient drugs and sedatives. Therefore, 40 dB $L_{night,outside}$ is equivalent to the LOAEL for night noise. Above 55 dB the cardiovascular effects become the major public health concern, which are likely to be less dependent on the nature of the noise. Closer examination of the precise impact will be necessary in the range between 30 dB and 55 dB as much will depend on the detailed circumstances of each case.

A number of instantaneous effects are connected to threshold levels expressed in $L_{Amax}$ (Table 5.1). The health relevance of these effects cannot be easily established. It can be safely assumed, however, that an increase in the number of such events over the baseline may constitute a subclinical adverse health effect by itself leading to significant clinical health outcomes.

Based on the exposure–effects relationship summarized in Table 5.4, the night noise guideline values are recommended for the protection of public health from night noise as below (Table 5.5).

**Table 5.5**
**Recommended night noise guidelines for Europe**

| | |
|---|---|
| Night noise guideline (NNG) | $L_{night,outside} = 40$ dB |
| Interim target (IT) | $L_{night,outside} = 55$ dB |

For the primary prevention of subclinical adverse health effects related to night noise in the population, it is recommended that the population should not be exposed to night noise levels greater than 40 dB of $L_{night,outside}$ during the part of the night when most people are in bed. The LOAEL of night noise, 40 dB $L_{night,outside}$, can be considered a health-based limit value of the night noise guidelines (NNG) necessary to protect the public, including most of the vulnerable groups such as children, the chronically ill and the elderly, from the adverse health effects of night noise.

An interim target (IT) of 55 dB $L_{night,outside}$ is recommended in the situations where the achievement of NNG is not feasible in the short run for various reasons. It should be emphasized that IT is not a health-based limit value by itself. Vulnerable groups cannot be protected at this level. Therefore, IT should be considered only as a feasibility-based intermediate target which can be temporarily considered by policy-makers for exceptional local situations.

All Member States are encouraged to gradually reduce the proportion of the population exposed to levels over the IT within the context of meeting wider sustainable development objectives. It is highly recommended to carry out risk assessment and management activities at local and national levels targeting the exposed population, and aiming at reducing night noise to the level below IT or NNG. IT and NNG can be used for health impact assessment of new projects (for example construction of roads, railways, airports or new residential areas) even before the achievement of IT, as well as for the risk assessment of the whole population. In the long run the NNG would be best achieved by control measures aimed at the sources along with other comprehensive approaches.

## 5.7 RELATION WITH THE GUIDELINES FOR COMMUNITY NOISE (1999)

The *Guidelines for community noise* (WHO, 1999) have been quoted a number of times in this paper, so one could rightfully ask what the relation is between the 1999 guidelines and the present NNG.

Impact of night-time exposure to noise and sleep disturbance is indeed covered in the 1999 guidelines, and this is the full statement (WHO, 1999):

> "If negative effects on sleep are to be avoided the equivalent sound pressure level should not exceed 30 dBA indoors for continuous noise. If the noise is not continuous, sleep disturbance correlates best with $L_{Amax}$ and effects have been observed at 45 dB or less. This is particularly true if the background level is low. Noise events exceeding 45 dBA should therefore be limited if possible. For sensitive people an even lower limit would be preferred. It should be noted that it should be possible to sleep with a bedroom window slightly open (a reduction from outside to inside of 15 dB). To prevent sleep disturbances, one should thus consider the equivalent sound pressure level and the number and level of sound events. Mitigation targeted to the first part of the night is believed to be effective for the ability to fall asleep."

It should be noted that the noise indicators of the 1999 guidelines are $L_{Aeq}$ and $L_{Amax}$, measured inside for continuous and non-continuous noise, respectively. The present night noise guidelines adopt an harmonized noise indicator as defined by Environmental Noise Directive (2002/49/EC): $L_{night}$ measured outside, averaged over a year.

It should also be borne in mind that the 1999 guidelines are based on studies carried out up to 1995 (and a few meta-analyses some years later). Important new studies (Passchier-Vermeer et al., 2002; Basner et al., 2004) have become available since then, together with new insights into normal and disturbed sleep.

Comparing the above statement with the recommendations, it is clear that new information has made more precise statements possible. The thresholds are now known to be lower than $L_{Amax}$ of 45 dB for a number of effects. The last three sentences still stand: there are good reasons for people to sleep with their windows open, and to prevent sleep disturbances one should consider the equivalent sound pressure level and the number of sound events. The present NNG allow responsible authorities and stakeholders to do this. Viewed in this way, the *Night noise guidelines for Europe* complements the 1999 guidelines. This means that the recommendations on government policy framework on noise management elaborated in the 1999 guidelines should be considered valid and relevant for the Member States to achieve the guideline values of this document.

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# APPENDIX 1. GLOSSARY OF TERMS AND ACRONYMS

| Term/acronym | Definition |
|---|---|
| Actimetry | The measurement of accelerations associated with the movement of an actimeter |
| ADHD | Attention-deficit hyperactivity disorder |
| Behavioural awakening | Awakening that is registered by the subject by means of a conscious action |
| BP | Blood pressure |
| CAP | Cyclic alternating patterns |
| EBD | Environmental burden of disease |
| END | Environmental Noise Directive (2002/49/EC) |
| EEG | Electroencephalogram, recording of electric activity in the brain |
| ECG | Electrocardiogram, recording of electric activity of the heart |
| EEG awakening | Transition from a state of sleep to a state of consciousness, as determined by a sleep EEG |
| Heart rate acceleration | A temporary rise in heart rate relative to the average heart rate assessed shortly before a noise event |
| HPA axis | Hypothalamus-pituitary-adrenal axis |
| ICSD | International Classification of Sleep Disorders |
| IHD | Ischaemic heart disease |
| Insomnia | Sleeping disorder consistent with an internationally accepted definition (see ICSD), which takes account of difficulty falling or staying asleep, the daytime implications and the duration of the problems |
| $L_{Aeq,T}$ | Exposure to noise for the duration of a given time interval T (a 24-hour period, a night, a day, an evening) is expressed as an equivalent sound pressure level (measured in dB(A)) over the interval in question |
| $L_{Amax}$ | Maximum outdoor sound pressure level associated with an individual noise event |
| $L_{night}$ | Refers to the EU definition in Directive 2002/49/EC: equivalent outdoor sound pressure level associated with a particular type of noise source during night-time (at least 8 hours), calculated over a period of a year |
| Motility onset | The presence of movement in a short time interval, following an interval without movement |
| Mg | Magnesium |
| Motility | The presence of movement in a short time interval, as recorded on an actigram |
| OR | Odds ratio: the ratio of the odds of an event occurring in another group, or to a sample-based estimate of that ratio |

| Term/acronym | Definition |
|---|---|
| OSAS | Obstructive sleep apnoea syndrome |
| OTC | Over-the-counter (medicines sold without prescription) |
| Polysomnography | The measurement during a subject's time in bed of his or her brain activity by means of EEG, EOG and EMG. The technique involves the use of electrodes to record electrical potentials in the brain |
| REM | Rapid eye movement (sleep phase) |
| RR | Relative risk: a ratio of the probability of the event occurring in the exposed group vs. the control (non-exposed) group |
| SEL | Sound exposure level: equivalent outdoor sound pressure level associated with an individual noise event, with the equivalent level standardized at one second |
| Sleep disturbance | Disturbance of sleep by night-time noise, as perceived by a subject and described in a questionnaire response or journal entry |
| Sleep EEG | Graph created using data from EEG scanning during a subject's time in bed, showing the various stages of sleep as a function of time |
| Sleep fragmentation | Within a sleep period, the frequency and duration of intervals of wakefulness recorded on a sleep EEG or intervals of motility recorded on an actigram |
| Sleep latency | The length of time taken to fall asleep, i.e. the interval between the point at which a person begins trying to go to sleep or allowing him/herself to go to sleep and sleep inception time |
| Sleep stage change | Change from a deeper stage of sleep to a less deep stage, as determined by a sleep EEG |
| SMR | Standardized mortality ratios |
| SROBD | Sleep related obstructive breathing disorders |
| SWS | Slow-wave sleep (sleep phase) |
| UARS | Upper airway resistance syndrome |

# APPENDIX 2. RELATIONS BETWEEN $L_{NIGHT}$ AND INSTANTANEOUS EFFECTS

## STATEMENT 1

Let f be a function of SEL that gives the expected number of instantaneous effects caused by a single event. With a given $L_{night}$ and a given number of events N, the expected number of times that an effect occurs in the night, n, is maximal if all events have equal SEL, provided that f°10lg is increasing but negatively accelerated.

## STATEMENT 2

If

$$n_{max} = 10^{(L_{night}\text{-}SEL+70.2)/10}.\ f(SEL),$$

has a maximum over SEL and f is the quadratic function $f(SEL) = a\ SEL^2 + b\ SEL + c$, then the maximum occurs irrespective of $L_{night}$ at

$$SEL_0 = 4.34 - A \pm ((A - 4.34)^2 - (c/a) + 8.68A)^{1/2},$$

where $A = b/(2a)$. (Only with + at the place of ± the value will come in the realistic range of SEL)

## STATEMENT 3A

If the shape of the time pattern of the sound level has a block form, then $SEL = L_{Amax} + 10lg(T)$, where $L_{Amax}$ is the maximum sound level (integrated over 1-s) and T is the duration of the noise event in seconds.

## STATEMENT 3B

If the sound level increases with rate a (in dB(A)/s) and after time point $t = 0$ decreases with rate –a, then $SEL \approx L_{Amax} - 10lg(a) + 9.4$.

# APPENDIX 3. ANIMAL STUDIES ON STRESS AND MORTALITY

## INTRODUCTION

Is noise a health risk or does it just annoy? This basic question needs to be carefully answered when establishing night noise guidelines. No one will deny that in the case of high noise levels there is a risk of inner ear damage, but what about the moderate levels of environmental noise? To approach this rather difficult question, all available methods must be combined.

1. In animal experiments it is possible to assess the complete causal chain from noise exposure via physiological reactions and biological risk factors to morbidity or even mortality. However, a quantitative application of the results to humans is not possible. Instead, the method is useful in studying the pathomechanisms qualitatively.
2. Experiments on humans are, for ethical reasons, restricted to the study of reversible physiological reactions. But as long as there is no proof that reactions to chronically repeated noise exposures are increasing the risk of specific diseases, the results of such physiological studies are not considered conclusive.
3. Epidemiological studies have the advantage of investigating health effects which are particularly caused by chronic noise exposure although there is no possibility to control all influencing factors. Additionally, epidemiological studies have to be based upon biologically evident hypotheses.

A hypothetical model of noise-induced health effects is shown in Fig. 4.3 in Chapter 4, section 4.5.2 of this report. This model is based on the results of noise experiments with animals and humans. With animal experiments, the whole causal chain from noise exposure to health outcome can be traced as a direct pathway starting with a chronic high level noise exposure which, via endocrine stress reactions, leads, for example, to microcirculatory defects and to manifest hypertension.

Physiological experiments on humans have shown that noise of a moderate level acts via an indirect pathway and has health outcomes similar to those caused by high noise exposures on the direct pathway. The indirect pathway starts with noise-induced disturbances of activities such as communication or sleep. Since we are dealing with night noise guidelines, noise-induced sleep disturbances and any resulting persistent health effects are of primary interest here.

In physiological studies with experimentally changed noise exposure, the increase of arousals and of hormone excretion was studied in sleeping people. If this model is correct then in the cause–effect chain the arousal ought to precede the endocrine reactions. This order was derived from the different reaction times of the effects. While arousals appear within 1 second after a noise stimulus, hormones like catecholamines take several minutes, and cortisol about 10 minutes to be increased. This observation, together with the fact that arousals are evoked by equal or lower noise levels than the corresponding endocrine reactions, confirms the correctness of the model and leads to an important conclusion: noise exposure which does not evoke arousals in sleeping people will not induce adverse health effects.

This conclusion is essential with regard to night noise guidelines. However, the answers to the basic question as to whether certain health risks are connected with environmental noise must be clarified by epidemiological studies based on noise experiments on both humans and animals.

## TYPES OF ANIMAL STUDIES

Noise has often been used as a stressor in animal studies. Even Selye (1953), who introduced the psychophysiological stress concept, used noise stimuli in his animal studies. Most of the modern animal studies testing the pharmacological effects of drugs are carried out with and without various stressors. The typical noise exposure is to short and very intensive sounds. One such example is the study of Diao et al. (2003) who exposed guinea pigs to 4 kHz octave band noise at 115 dB for 5 hours. But these experiments are of little value regarding the noise exposure types in question.

The same is true for another type of animal study concerned with the prevention of noise-induced health effects in wild and domestic animals (for review of the former kind see Fletcher, 1983). One example for the latter kind is the study of Geverink et al. (1998) on stress responses of pigs to transport and lairage sounds.

Since the subject of the present paper is noise-induced health effects in humans, the review addresses only those studies in which animals are used as a model for humans.

The animal model for aural effects in humans has been established in great detail, so that even quantitative transference of results from animals to humans is possible. However, inner ear damage generally occurs at much higher noise levels than the environmental levels under discussion in this paper. Therefore interest focuses on animal models with respect to extra-aural noise effects.

## LIMITING ASPECTS OF ANIMAL MODELS

Other than in studies on aural effects, the animal model does not allow quantitative comparisons in studies of extra-aural noise effects. It may, however, be used for the qualitative investigation of pathophysiological mechanisms following exposure to acute and very short sounds. But an animal model for long-term noise effects as caused by chronically repeated noise exposures needs careful planning. First it has to be ensured that stress reactions in both humans and animals when activated by noise exposure are qualitatively comparable. Secondly, the stress effects of chronic noise exposure have to be assessed in humans, and the animal models should be designed correspondingly. However, in the animal model, influences from cortical interconnections have to be excluded as a factor in these noise experiments. Naturally, one cannot expect to establish an animal model for indirect environmental noise effects which in humans may, for example, disturb activities such as verbal communication, which in turn may induce stress hormone increases.

## STRESS HORMONES IN NOISE-EXPOSED ANIMALS

### HABITUATION

In short-term experiments any kind of exposure to loud noise will cause acute increases of stress hormones. Long-term repeated noise exposure, however, will cause a certain habituation in the animal. Periodic repetitions of identical noise bursts lead to almost complete habituation. This was probably the main reason why Borg (1981) found no adverse health effects in rats exposed for their whole lives to periodic noise pulses. Therefore, random series of noise pulses are now applied in most long-term studies.

Selye (1974) had already stated that not all stages of a stress response are noxious, especially in the case of mild or brief exposures. Since environmental noise is a mild stressor, adverse health effects are only to be expected under the condition that repeated noise exposures induce long-term stress hormone changes. According to the Allostatic Load Model (McEwen, 1998), the normal response to an environmental stressor such as noise is the physiological activation of the endocrine system enabling the body to cope with the stressor and, after the stress situation is terminated, to shut off the allostatic response.

## J.D. HENRY'S MODEL OF BEHAVIOURAL STRESS EFFECTS

On the basis of the available literature on stress effects in animals and humans, Henry (1992) developed a model with regard to different biological effects and health risks associated with different coping styles. He explains that the neuroendocrine response to various challenges and threats varies according to the type and degree of control a mammal can exert over it. This in turn is strongly determined by the animal's previous experience. In general, the sympathetic adrenomedullary system is preferentially activated when the animal displays an active response to escape from or deal with an environmental challenge. This is the fight/flight mode of stress response. The adrenocortical axis is preferentially activated as the subjects become immobile/passive when no control or threat of its loss is experienced. This is the conservation/withdrawal mode of response.

## THE NOISE STRESS MODEL

On the basis of noise effect studies in animals and humans (for review see Ising and Braun, 2000), a noise stress model was developed. It describes a differentiation of prevailing "stress hormones" under noise exposure. Predominantly adrenaline – and to a lesser degree noradrenaline – are released from the adrenal medulla as the normal response to novel noise stimuli of moderate intensity. Following long-term noise exposures of moderate intensity habituation will alter the response mode and predominantly noradrenaline is released. As a response to extremely intensive noise, near the inner ear pain threshold, predominantly cortisol is released from the adrenal cortex induced by increased releases of adrenocorticotropic hormone (ACTH), especially in the case of unexpected noise.

The described differentiation will only be observed under special conditions. Unexpected exposure for three minutes to white noise at 75 dB leads, in dogs that are awake, to increased adrenal secretion of adrenaline and noradrenaline and – following a delayed increase in plasma ACTH – an increase in cortisol secretion (Engeland, Miller and Gann, 1990).

The cortisol response as described is valid for animals and humans in their active phases. During sleep, however, several studies in humans showed cortisol increases under exposure to traffic noise of moderate levels (Maschke, Arndt and Ising, 1995;

Evans et al.2001; Ising and Ising, 2002; Ising et al., 2004). It was hypothesized that noise stimuli signalling a danger, for example the noise of an approaching lorry, will, during sleep, normally generate a defeat reaction, which includes the release of cortisol from the adrenal cortex. Appropriate studies with sleeping animals after conditioning them – for example with a specific noise stimulus followed by pain – should be carried out to test this hypothesis.

Rats were exposed for a period of 12 hours to low-altitude flight noise – reproduced electro-acoustically once per hour on average at stochastically fluctuating intervals ($L_{Amax}$ 125 dB, 10 dB downtime: 1 s, $L_{eq}$: 89 dB) (Ising et al., 1991; Ising, 1993). Adrenaline and noradrenaline excretions tended to decrease, whereas plasma cortisol increased significantly. Although in rats corticosterone is secreted rather than cortisol, we will simplify this paper by using cortisol for rats all the same. In this experiment, as well as in all others of our group, normally four rats were kept in one stainless steel cage, which was set on a funnel to collect their urine.
These results show that exposure to noise levels approaching or exceeding the pain threshold of the inner ear leads to endocrine reactions qualitatively different from those induced by less intensive noise.

The different endocrine reactions to acute and chronic noise exposure were studied in rats by Gesi et al. (2002b). They were exposed either to a single (6-hour) session of loud (100 dB(A)) noise, or to the same noise stimulus repeatedly every day for 21 consecutive days. Exposure to noise for 6 hours on one day induced parallel increases in dopamine, noradrenaline and adrenaline concentrations in tissue samples of the adrenal medulla. After 21 days of noise exposure, noradrenaline concentration was significantly higher than in controls, and that of adrenaline decreased significantly. Cortisol was not assessed in this study.

In another subchronic noise experiment, rats were exposed to irregular white noise at 90 dB for 3 and 9 hours per day during 18 and 8 days respectively (van Raaij et al., 1997). In rats with 3 hours of exposure per day the blood concentrations of adrenaline, noradrenaline and cortisol did not differ from controls. Exposure for 9 hours per day, however, resulted in significantly increased concentrations of noradrenaline and cortisol. At the end of the experiment all animals were subjected to restraint stress and their endocrine reactions were assessed. The authors sum up their findings as follows: these results indicate that chronic noise exposure at mild intensities induces subtle but significant changes in hormonal regulation.

The results of another experiment with different levels of random white noise pulses during 45 minutes per hour, 12 hours per day for 8 days demonstrate that cortisol responses to subchronic mild noise exposure do not monotonously increase with the noise levels (Bijlsma et al., 2001). While in rats exposed to 95 dB pulses plasma cortisol concentrations were raised twofold against controls, the exposure to 105 dB pulses did not increase cortisol significantly.

The time dependency of cortisol increase in the blood of rats under exposure to white noise (100 dB, 6 hours per day for 21 days) was examined by Gesi et al. (2001). The authors found a progressive increase in cortisol which reached a plateau 9 days from the beginning of exposure.

In summing up the results of these studies we can reach the following conclusions.

- Acute exposure to unexpected and novel noise of moderate intensities leads to activation of both the sympathetic adrenal-medullary system with increased secretion of adrenaline and noradrenaline, and the HPA axis with increased secretion of ACTH and of cortisol from the adrenal cortex.

- Under chronic exposure to unpredictable noise, adrenaline secretion is reduced to normal or subnormal values while noradrenaline and ACTH/cortisol concentrations remain increased.

- Extremely intensive unpredictable noise near the inner ear pain threshold triggers, in mammals that are awake, a defeat reaction with increases of ACTH/cortisol while the catecholamines adrenaline and noradrenaline remain normal or are slightly decreased.

- Chronic noise exposure at mild intensities will induce changes in hormonal regulation, if the individual threshold of allostasis is exceeded. A chronic allostatic load leads to subtle but significant changes in hormonal regulation, which are at present not fully understood.

## EFFECTS OF PRENATAL NOISE EXPOSURE ON THE SENSITIVITY TO STRESS

Pregnant rats were subjected to noise and light stress, three times weekly on an unpredictable basis throughout gestation (Weinstock et al., 1998). Blood concentrations of adrenaline, noradrenaline and cortisol at rest and after footshock were assessed. At rest cortisol was significantly increased in offspring of stressed rats in comparison to controls while adrenaline and noradrenaline did not differ in either of the groups. After footshock, noradrenaline was significantly higher in offspring of stressed rats, showing that prenatal stress can induce long-term changes in the sensitivity of the sympathicoadrenal system to stress.

Pregnant monkeys were repeatedly exposed to unpredictable noise during days 90–145 after conception (Clarke et al., 1994). Blood concentration of ACTH and cortisol were measured in offspring of stressed and control monkeys at rest and under four progressively stressful conditions. Prenatally stressed offspring showed higher ACTH than controls in all four stressful conditions while cortisol did not change under stress. These results indicate that prenatal stress may have long-term effects on the HPA axis regulation.

## EFFECTS OF NOISE EXPOSURE ON CORTISOL AND THE IMMUNE SYSTEM

The effect of acute noise stress on rats was studied by assessing blood concentrations of cortisol and total as well as differential leukocyte count (Archana and Namasivayam, 1999). A significant increase in cortisol and a significant decrease of total leukocyte counts were found.

Rats were exposed to "rock" music (80dB) for 24 hours (McCarthy, Quimet and Daun, 1992). In vitro stimulation of leukocyte subpopulations revealed several noise effects. Neutrophils and macrophages secreted significantly less superoxide anion and interleukin-1. Such effects may be detrimental to wound healing.

Pregnant rats were from gestation day 15 to day 21 daily exposed to the noise of a fire alarm bell ($L_{Amax}$ = 85–90 dB) delivered randomly for 1 hour (Sobrian et al., 1997). In developing offspring mitogen-specific alterations in lymphoproliferatic activity and reduced immunoglobulin G levels were found at postnatal day 21.
Aguas et al. (1999) exposed a special breed of mice to low frequency noise – a model of noise – for three months as described below (Castelo Branco et al., 2003). These mice spontaneously developed an autoimmune disease at 6 months of age. Chronic low frequency noise exposure accelerated the expression of the autoimmune disease and affected the immune system, which was associated with kidney lesions and increased mortality.

*Embryotoxic effects*
Geber (1973) exposed pregnant rats day and night for three weeks to constantly changing sound mixtures between 76 and 94 dB for 6 minutes per hour, day and night, and demonstrated embryotoxic effects, notably calcification defects in the embryos.

Pregnant rats on a moderately magnesium deficient diet were exposed to noise during their active phase from 20.00 to 08.00 for three weeks (stochastically applied white noise impulses $L_{Amax}$: 87 dB, $L_{eq}$: 77 dB, t: 1 s duration) (Günther et al. 1981).

As compared to controls on the same diet, there was no difference in bone mineralization. The only significant effect was an increased fetal resorption rate.

The noise was changing in Geber's experiment but the noise level was comparable to the noise impulses stochastically applied by Günther et al. ($L_{Amax}$ = 87 dB). Since these impulses were more frequent, their stress effect was at least as strong as the noise exposure employed by Geber. Therefore the major factor that differentiated the two exposure types in causing a reduced mineralization of the rat skeletons (Geber, 1973) must have been the additional noise exposure during sleep.

Castelo Branco et al. (2003) studied Wistar rats born under low frequency noise exposure. The third octave level of the applied broadband noise was > 90 dB for frequencies between 50 and 500 Hz. The broadband level was 109 dB(lin). The exposure schedule was chosen as a model for occupational noise: 8 hours per day, 5 days per week, and weekends in silence. Third generation rats born in low frequency noise environments were observed showing teratogenic malformations including loss of segments.

*Morphological alterations in the myocardium caused by acute noise*
Gesi et al. (2002a) reviewed the literature and stated that in experimental animals undergoing noise exposure, subcellular myocardial changes have been reported, especially at mitochondrial level; in particular, after 6 hours of exposure only the atrium exhibited significant mitochondrial alterations, whereas after 12 hours as well as subchronic exposure both atrium and ventricle were damaged.

Exposure of rats to 100 dB(A) noise for 12 hours caused a significant increase of DNA damage accompanied by ultrastructural alterations and increased noradrenaline concentrations in the myocardium (Lenzi et al., 2003). In another paper this group described an increase in mitochondrial calcium (Ca) influx caused by the same noise exposure. They described Ca accumulation at myocardial subcellular level. Summing up their results they wrote that: moreover, the present results joined with previous evidence indicate that calcium accumulation is the final common pathway responsible for noise-induced myocardial morphological alterations (Gesi et al., 2000).

*Connective tissue proliferation*
Hauss, Schmitt and Müller (1971) described a proliferation of connective tissue in the myocardium of rats under acute exposure to noise.

On the basis of these results a noise exposure experiment was carried out of 5 weeks with day and night exposure to stochastically triggered bells ($L_{Amax}$: 108 dB, t (duration of one signal):1 s, $L_{eq}$: 91 dB) (Ising, Noack and Lunkenheiner, 1974). We confirmed the results of Hauss, Schmitt and Müller (1971) using an electron microscope to demonstrate fibrosis in the interstitial tissue of the myocardium. Additionally electron dense areas (visible as black spots) located within bundles of collagen in the myocardium were observed. According to Selye (1962), these dark areas were most probably caused by high concentrations of calcium (Ca) carbonate or calcium phosphate deposits. This suggestion is consistent with the results of Gesi et al. (2000).

After publication of these findings, a reservation was correctly voiced that, as the noise exposure had not left intervals for sleep, it was not certain whether the myocardial damage was provoked by the noise stress as such or by a noise-induced lack of sleep. For this reason, all subsequent experiments provided for noise-free intervals of 8 to 12 hours during the rats' inactive phases to enable them to sleep.

Rats were exposed for 28 weeks to a random series of white noise impulses from 16.00 to 08.00 daily with an 8 hour rest in their inactive phase (Ising et al., 1979). The third octave spectrum of the noise was flat between 5 and 25 kHz and had a third octave level of 88 dB (lin) (broadband $L_{Amax}$ = 97 dB(lin). $L_{eq}$ = 87 dB(lin)). The duration of noise impulses was 4 seconds and the noise to pause ratio 1:10 on average. There was a small but significant increase in hydroxyproline as indicator of collagen in the rats' left myocardium. Electron micrographs showed, similar to the earlier experiment, collagen bundles in the otherwise empty interstitial space but no indication of calcium deposits.

*Respiratory effects*
Castelo Branco et al. (2003) studied respiratory epithelia in Wistar rats born under low frequency noise exposure and further exposed for up to 5403 hours during more than 2.5 years. The third octave level of the applied broadband noise was > 90 dB for frequencies between 50 and 500 Hz. The broadband level was 109 dB(lin). The exposure schedule was chosen as a model for occupational noise: 8 hours per day, 5 days per week and weekends in silence. Rats were gestated and born under the described noise exposure with additional exposures from 145 to 5304 hours. Transmission electron micrographs of the tracheal epithelium of rats exposed for 2438 hours revealed a subepithelial layer of hyperplastic collagen bundles, several of them exhibiting a degenerative pattern. The results indicate an increased proliferation as well as degenerative processes of collagen.

Castelo Branco et al. (2003) observed sheared cilia in the respiratory epithelia of Wistar rats born under and further chronically exposed to low frequency noise. As interpretation of their findings they stated that both mechanical and biochemical events may be responsible for this pattern of trauma.

*Electrolytes: Ca/Mg shift*
Acute exposure of rats to the fast rising overflight noise of low flying fighter planes

reaching levels of up to 125 dB(A) ) (Ising et al., 1991; Ising, 1993) resulted not only in an increase of cortisol but also in a decrease of intracellular magnesium (Mg) and an increase of Mg excretion.
In guinea pigs, acute stress – due to 2 hours of noise exposure (95 dB white noise) or to overcrowding in the cage – caused significant increases of serum Mg and decreases of erythrocyte Mg (Ising et al., 1986).

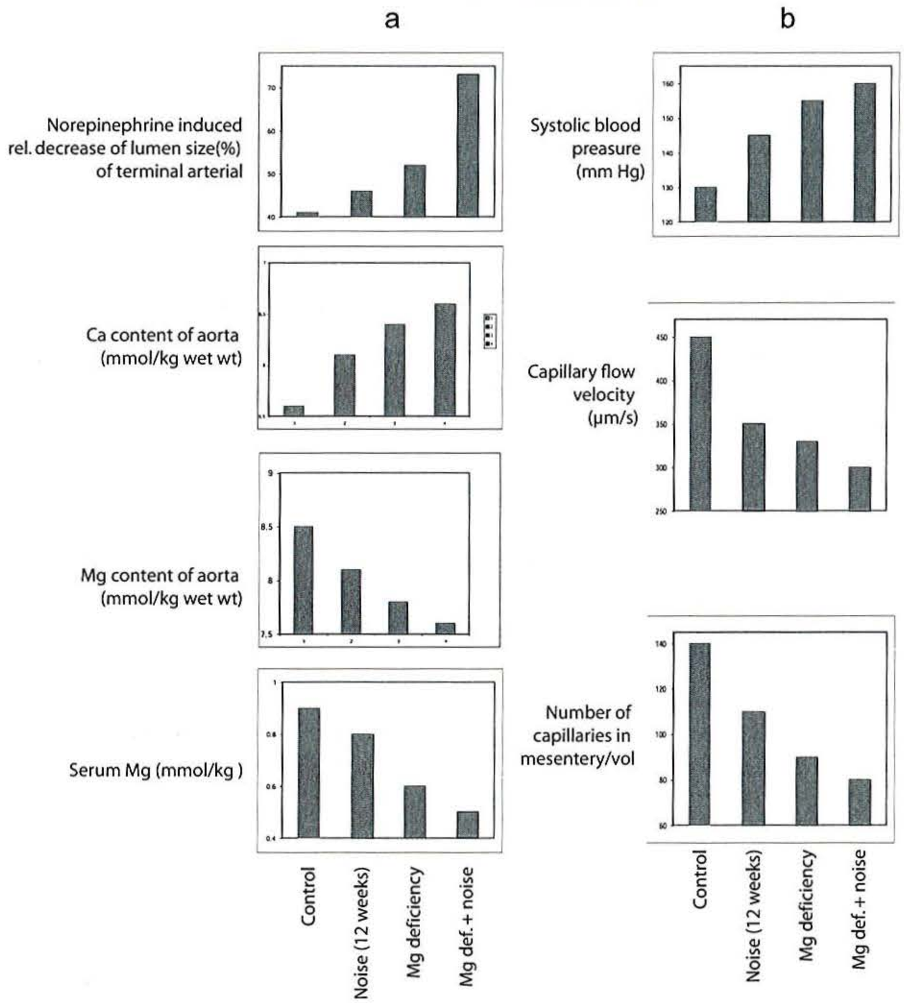
For chronic noise experiments an additional stress factor had been sought which would act synergistically with unwanted noise, since in the above described noise experiment, half a year of exposure led to but relatively mild health effects (Ising et al., 1979). The justification for using two stressors derives from the fact that humans have to cope with a whole range of more or less synergistic stress factors and not with noise alone.

Organic damage as a result of chronic stress is likely to occur only under the condition that the overall exposure to stress exceeds a certain tolerance level during a relatively long period of time (Selye, 1974). For technical reasons, the two options available to supply a suitable additional stress factor were the cold or a magnesium (Mg) deficiency. Both factors, like habitual noise, cause an increased noradrenaline secretion. For practical reasons different degrees of a magnesium-deficient diet were selected as an additional stress factor. Noise exposure was provided by electro-acoustically reproduced traffic noise of $L_{Amax}$: 86 dB, $L_{eq}$: 69 dB over 12 hours during the rats' active phase. For one group the noise level was slightly increased ($L_{eq}$: 75 dB). The experiment lasted 16 weeks (Günther, Ising and Merker, 1978). Magnesium deficiency combined with noise exposure led to dose-dependent increases in adrenaline and noradrenaline, which can be used to quantify the overall stress of the dietary treatment. As stress grew, the hydroxyproline (as an indicator of collagen) and calcium (Ca) content of the myocardium increased while the magnesium content decreased. Long-term stress therefore resulted in an intracellular Ca/Mg shift.

Altura et al. (1992) studied the relationship between microcirculation (measured several days after termination of noise exposure), hypertension and Ca/Mg shifts in vascular walls of noise-stressed rats on Mg deficient diets. Noise exposure during the first 8 weeks was set to an energy equivalent level of 85 dB(A) from 20.00 to 08.00. Noise impulses were randomly switched on at randomized peak levels of 80, 90 and 100 dB(A). During the final 4 weeks the equivalent noise level was elevated to 95 dB(A) and the daily exposure increased to 16 hours with an 8 hour rest during the animals' inactive phase. In aortic and port vein smooth muscle the Ca content increased with rising noise exposure, with decreasing Mg uptake, and with the combination of both together, while the Mg content decreased. Parallel to this the reactivity of terminal arterioles to noradrenaline was increased (Fig.1a).

Stress-induced Ca/Mg shifts in smooth muscle cells have the potential to increase the risk of hypertension and myocardial infarction (Ising, Havestadt and Neus, 1985). Stress increases the membrane permeability of catecholamine-sensitive cells, which in turn raises Ca influx into cells and liberates intracellular Mg. A depression of catecholamine-induced vasoconstriction by stress-dependent hypermagnesemia (excess serum Mg concentration) has been demonstrated experimentally. However, the benefit from this stress-depressing hypermagnesemia is obtained at the expense of increased renal Mg loss. In the long run, chronic stress combined with suboptimal Mg in diet will reduce the Mg release in acute stress situations, causing an increase of vasoconstriction and raising the risk of hypertension.

**Fig.1**
**Effects of 12 weeks noise exposure, Mg deficient diet and the combination of both in Wistar rats. (a) Ca/Mg shifts in vascular smooth muscle, Mg concentration in blood and reactivity of arterioles to noradrenaline. (b) Systolic BP, capillary blood flow velocity and numbers of capillaries/volume.**




*Source: Altura et al., 1992*

Further analysis of the experimental results led to an interaction model between chronic stress and intracellular electrolyte shifts (Ising, 1981; Ising et al., 1986) (Fig.2). Chronic stress caused a loss of extracellular and intracellular Mg and an increase in intracellular Ca (Günther, Ising and Merker, 1978). A decrease of Mg was correlated with an increase in physiological noise sensitivity, that is, to more severe noradrenaline releases in animals and humans under noise exposure (Günther, Ising and Merker, 1978; Ising, Havestadt and Neus, 1985; Ising et al., 1986). There was a positive feedback mechanism between stress – caused by noise and other stressors – and intracellular Mg/Ca shifts, which may end in a circulus vitiosus and increase cardiovascular risks.



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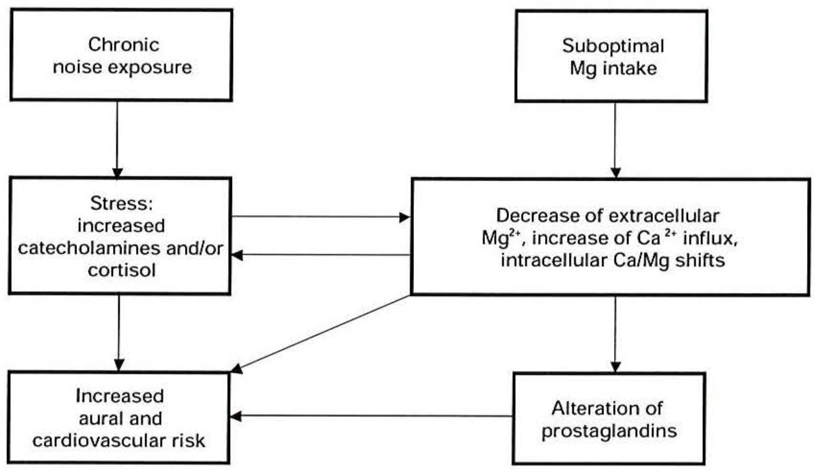
**Fig. 2**
**Interaction between stress and Ca/Mg shifts and its long term consequences**




*Hypertension*
Rothlin, Cerletti and Emmenegger (1956) exposed rats for 1.5 years, day and night, to 90 dB "audiogenic stress" and observed a raising of systolic BP values from 120 mm Hg to about 150 mm Hg. He used a cross-breed of Albino rats and wild Norwegian rats since Albino rats did not develop hypertension under noise exposure. After termination of exposure the BP returned to normal.

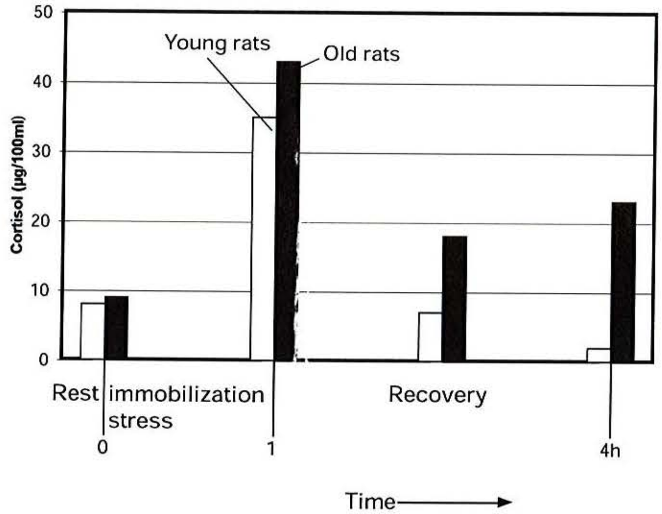
Albino rats were exposed to noise during their whole lifespan (for review see Borg, 1981) to periodic noise impulses of 80 and 100 dB. This periodic exposure had no detrimental health effects, which can be understood on the basis of the work of Glass, Singer and Friedmann (1969). Unpredictable noise presentation was shown to cause lasting cortisol increases in rats in contrast to periodic exposure to 100 dB, which led to adaptation (De Boer, van der Gugten and Slangen, 1989). The unpredictability of a noise is a decisive precondition of long-term stress effects.

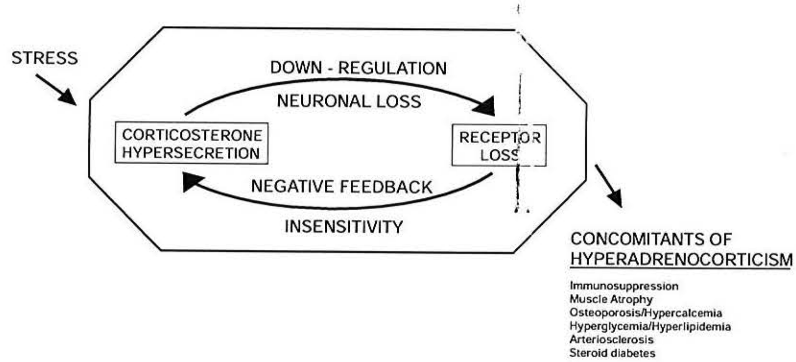
Exposure of primates to traffic noise for 10 hours per day during 9 months led to a significant BP increase, which persisted during 3 weeks after termination of exposure (Peterson et al., 1981). A replication of this experiment with a different species of primates failed to show an increase of their BP (Turkkan, Hienz and Harris, 1983).

In the above-mentioned experiment of Altura et al. (1992), exposure to unpredictable noise impulses led within 12 weeks to irreversible changes of microcirculation and an increase of systolic BP (Fig. 1b). The observed rarefication of capillaries in the mesentery can be interpreted as an indicator of accelerated ageing of the circulatory system.

*Ageing and lifespan*
The cortisol response and recovery after immobilization stress was compared in young and old rats. The results are demonstrated in Fig. 3 together with Sapolsky's Glucocorticoid Cascade Model (Sapolsky, Krey and McEwen, 1986). The stress response of young and old rats is more or less the same. However, while the young rats recover immediately after termination the old ones recover only in part.

**Fig. 3**
**Above: Recovery after stress (young and old rats). Below: Sapolsky´s Glucocorticoid Cascade Model**




Therefore, acute stress leads, in old animals, to considerably prolonged cortisol increases. On the other hand, chronically repeated stress activates the HPA axis and can cause cortisol receptor losses even in younger animals, a process generally developing only in old age. Finally, chronic cortisol hypersecretion may occur along with follow-up health defects.

Aguas et al. (1999) exposed a special breed of mice to the above described model of occupational low frequency noise for three months. Chronic low frequency noise exposure accelerated the expression of the autoimmune disease and was associated with kidney lesions and increased mortality.

Chronic noise exposure of animals on a suboptimal Mg diet led to increases of connective tissue and calcium and decreases of Mg in the myocardium (Günther, Ising and Merker, 1978). These changes were correlated with noradrenaline changes. Since they are also correlated with normal ageing, the noise stress induced changes may be interpreted as accelerated ageing (Ising, Nawroth and Günther, 1981). Even the lifespan was reduced in rats on an Mg deficient diet, and was further dose-dependently reduced in combination with noise exposure (see Table 1).

**Table 1**
**Effects of noise exposure combined with dietary Mg-deficiency in rats**

| Treatment | | Effect | | | | | |
|---|---|---|---|---|---|---|---|
| 4 months | 3 months | Urine | | Myocardium | | | Death rate |
| Mg in diet | Noise | Noradre-naline | Adre-naline | Hydroxy-proline | Ca | Mg | |
| | $L_{eq}/L_{Amax}$ | (µg/g Cre) | | (mg/g dry wt.) | (mg/g d.w.) | (mg/g d.w.) | |
| control | ambient | 18 ± 4 | 12 ± 2 | 3.0 ± 0.1 | 3.0 ± 0.2 | 37.5 ± 0.8 | 0 |
| suboptimal | ambient | 23 ± 4 | 18 ± 2 | 3.0 ± 0.1 | 3.5 ± 0.5 | 38.0 ± 1.7 | 0 |
| suboptimal | 69/86 dB | 37 ± 11 | 16 ± 2 | 3.0 ± 0.1 | 4.3 ± 0.2 | 37.9 ± 1.3 | 0 |
| deficient | ambient | 98 ± 17 | 20 ± 5 | 3.9 ± 0.1 | 6.2 ± 0.7 | 31.2 ± 1.4 | 38% |
| deficient | 69/86 dB | 129 ± 19 | 41 ± 10 | 4.6 ± 0.1 | 6.7 ± 0.6 | 29.8 ± 1.8 | 62% |
| deficient | 75/86 dB | 172 ± 26 | 60 ± 15 | 5.6 ± 0.9 | 8.0 ± 0.9 | 26.8 ± 0.8 | 75% |

Adrenaline and noradrenaline excretion was measured during the fourth week of noise exposure; death rate is related to the 4-month period of Mg treatment; all other parameters were determined at the end of the experiment (mean values ± S.E.). Noise has the potential to cause stress reactions which are enhanced by suboptimal magnesium intake. Chronic noise-induced stress accelerates the ageing of the myocardium and thus increases the risk of myocardial infarction. The involved pathomechanisms include increases of catecholamines and/or cortisol under acute noise exposure and an interaction between endocrine reactions and intracellular Ca/Mg shifts.

## WHAT CAN BE LEARNED FROM ANIMAL STUDIES ABOUT NOISE EFFECTS IN HUMANS?

The effects of low frequency noise – the "vibroacoustic disease" – were studied primarily in humans (for review see Castello Branco and Alves-Pereira, 2004).

In this context, the amygdalar contribution to conditioned fear learning, revealed for normal human subjects, has to be mentioned. Longer lasting activation of the HPA axis, especially abnormally increased or repeatedly elevated cortisol levels may lead to disturbances of the hormonal balance and even severe diseases in man (Spreng, 2000).

Catecholamines induce various detrimental effects on the heart (Ceremuzynski, 1981). Additionally, magnesium deficiency causes alterations of serum lipids (Weglicki et al., 1993), cytokines (Rayssiguier, 1990) and prostaglandines (Nigam, Averdunk and Günther, 1986), in particular an increase of thromboxan, which is released from thrombocytes (Neumann and Lang, 1995) and several other cell types and – in turn – thromboxan A2 can aggregate thrombocytes. All these alterations may increase the risk of myocardial infarction.
Beside these cardiovascular stress effects, chronically increased cortisol may induce

neuronal degeneration and thus accelerate the ageing also of the brain (Sapolsky, Krey and McEwen, 1986), not only in rats but in humans as well (Sapolsky, 1994).

The importance of Ca/Mg shifts was confirmed by post mortem studies of hearts from victims of IHD (Elwood et al. 1980). The tissue samples were taken from areas of the myocardium not affected by the infarction and the results were stable after controlling for several confounders. The results are shown in Table 2. With normal ageing Ca increases and Mg decreases in the myocardium. This process is accelerated in myocardial infarction patients, which indicates an accelerated ageing of these peoples' heart muscle under the pathogenic influences that lead to myocardial infarction.

**Table 2**
**Age dependency of myocardial Ca and Mg contents in ischaemic heart disease (IHD)**

**IHD deaths and non IHD deaths. (Mean Value ± SD, numbers in brackets)**

| | Group | Age < 45years | 45–64 years | ≥ 65 years |
|---|---|---|---|---|
| Ca [μg/g] | Non IHD | 43 ± 15 (175) | 50 ± 14 (281) | 57 ± 22 (155) |
| | IHD | 48 ± 10 (48) | 53 ± 17 (389) | 58 ± 21 (188) |
| Mg [μg/g] | Non IHD | 183 ± 28 | 173 ± 34 | 178 ± 30 |
| | IHD | 170 ± 29 | 157 ± 30 | 156 ± 27 |
| Ca/Mg | Non IHD | 0.24 | 0.29 | 0.32 |
| | IHD | 0.28 | 0.34 | 0.37 |

Another factor which decreases Mg and increases Ca (Hofecker, Niedermüller and Skalicky, 1991) and collagen (Caspari, Gibson and Harris; 1976, Anversa et al., 1990; Gibbons, Beverly and Snyder, 1991) in the myocard is normal ageing (Ising, Nawroth and Günther, 1981). Therefore, it is plausible that the age-dependent decrease of Mg in hearts of IHD victims was about double of that in age-matched non-IHD deaths. This is therefore an indication that age- and stress-dependent electrolyte changes exist in humans and may be correlated with an increased risk of IHD.

Long-term experiments with Mg-deficient and noise-stressed rats showed that connective tissue and Ca in the myocardium increased with age while Mg decreased. Hence, stress caused by noise or cold is enhanced by suboptimal Mg intake and accelerates the ageing of the heart and decreases the lifespan (Heroux, Peter and Heggtveit, 1977; Ising, Nawroth and Günther, 1981; Günther, 1991).

Since coronary arteriosclerosis increases strongly with age (Lakatta, 1990) a biologically older heart is at a higher risk of IHD and of myocardial infarction. The interaction process described seems to be one of the pathomechanisms by which chronic noise stress increases the risk of myocardial infarction.

Several of the risk factors described in the literature to explain the correlation of work stress with myocardial infarction have been found to be increased under noise-induced stress as well, that is, increases of BP and total cholesterol.

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# APPENDIX 4. NOISE AND SLEEP IN CHILDREN

## FACTORS THAT MODIFY AUDITORY AROUSAL THRESHOLDS IN CHILDREN

By the time that most studies were conducted in infants, it had become progressively evident that arousal and awakening thresholds are influenced by a variety of factors. These significantly modify the response to ambient noise of sleeping infants. Some factors inhibit the arousal response, while others enhance the response.

### PRENATAL AND PERINATAL FACTORS

*Age of gestation*
In 97 healthy infants, auditory awakening thresholds decreased significantly from the 44th to the 60th week after conception (Kahn, Picard and Blum, 1986). Awakening thresholds were defined as the infant opening their eyes and/or crying. Mean awakening thresholds dropped from 98.5+/-11 at the 44th week after conception to 83 dB(A) by the 60th week after conception.

*Cigarette smoke*
To evaluate the effects of cigarette smoke on polygraphic arousal thresholds, 26 newborns were studied with polygraphic recordings for one night: 13 were born to mothers who did not smoke, and 13 were born to mothers who smoked (over 9 cigarettes per day) (Franco et al., 1999). Another group of infants with a median postnatal age of 12 weeks were also studied: 21 born to non-smoking mothers and 21 born to smoking mothers. The auditory arousal thresholds of the infants of both age groups were measured with the use of auditory challenges of increasing intensity, administered during REM sleep. More intense auditory stimuli were needed to induce arousals in newborns (p=.002) and infants (p=.044) of smokers than in infants of non-smokers (mean value of 84+/-11 dB(A) for smokers and 81.6+/-20 for non-smokers). Behavioural awakening (infants opening their eyes and/or crying) occurred significantly less frequently in the newborns of smokers (p=.002) than of non-smokers.

It was concluded that newborn and infants born to smoking mothers had higher arousal thresholds to auditory challenges than those born to non-smoking mothers. From the present findings, it appeared that the impact of exposure to cigarette smoke occurred mainly before birth.

### POSTNATAL FACTORS

The following postnatal factors modify arousal from sleep.

*Sleep stage*
In infants, auditory stimuli have generally indicated increased responses during active as compared with quiet sleep (Busby, Mercier and Pivik, 1994).

*Time of the night*
In 31 infants, the arousal thresholds decreased across the night (mean value of 67+/-12.5 dB(A) in the first part of the night, for 51+/-3.5 in the third part of the night; p=.017) (Franco et al., 2001). Similar findings had been reported in adult subjects (Rechtschaffen, Hauri and Zeitlin, 1966).

*Body position during sleep*
To investigate whether prone or supine sleeping was associated with a different response threshold to environmental stimuli, 25 3-month-old healthy infants with a median age of 9 months were exposed to an auditory challenge while sleeping successively prone or supine (Franco et al., 1998). Three infants were excluded from the study because they awoke while their position was being changed. For the 22 infants included in the analysis, more intense auditory stimuli were needed to arouse the infants in the prone position (median of 70 db(A), range values 50 to more than 100 db(A)) than in the supine position (median of 60 db(A), range values 50–90 db(A)) (p=.011). Arousal thresholds were higher in the prone than in the supine position in 15 infants, unchanged in 4 infants and lower in the prone position in 3 infants (p=.007). It was concluded that infants show higher arousal thresholds to auditory challenges when sleeping in the prone position than when sleeping in the supine position. The findings could not readily be explained. The difference in arousal thresholds could be related to difference in chest wall mechanoreceptor responses, or differences in BP and/or central baroreceptors responses.

*Ambient room temperature*
Two groups of healthy infants with a median age of 11 weeks were recorded polygraphically during one night: 31 infants were studied at 24°C and 31 infants at 28°C. To determine their arousal thresholds, the infants were exposed to white noises of increasing intensities during REM and non-REM sleep (Franco et al., 2001). The arousal thresholds decreased across the night in the infants sleeping at 24°C (p= .017). The finding was not found for the infants sleeping at 28°C. When analysing the arousal responses according to time of the night, it was found that the auditory thresholds were significantly higher at 28°C (75+/-19 dB(A)) than at 24°C (51+/-3.5 dB(A)) between 03.00 and 06.00 (p=.003). These findings were only seen in REM sleep.

*Sleeping with the head covered by bedclothes*
To evaluate the influence of covering the face of sleeping infants with a bed sheet, 18 healthy infants with a median of 10.5 weeks (range 8–15 weeks) were recorded polygraphically for one night (Franco et al., 2002). They slept in their usual supine position. During sleep, a bed sheet was gently placed on their face for 60 minutes. With the face free or covered by the sheet, the infants were exposed to white noises of increasing intensities during REM and non-REM sleep. Compared to with their face free, during the periods when their faces were covered, the infants had increases in pericephalic ambient temperature (p<.001), increases in REM sleep (p=.035) and body movements (p=.011) and a decrease in non-REM sleep (p<.001). Respiratory frequency was increased in both REM (p=.001) and non-REM (p<.001) sleep. With their face covered, the infants had higher auditory arousal thresholds (mean of 76+/-23 dB(A)) than with their face free (mean of 58+/-14 dB(A)) (p=.006). The difference was seen in REM sleep only. A positive correlation was found between pericephalic temperature and arousal thresholds in REM sleep (r=.487; p=.003).

*Short sleep deprivation*
Following short sleep deprivation, a study reported that in infants there was no measurable change in arousal propensity by auditory stimuli (1 kHz pure tone, delivered in the midline of the cot, from 73 dB and increased in 3 dB steps to 100 dB)

during quiet sleep (Thomas et al., 1996). Another study was undertaken to evaluate the influence of a brief period of sleep deprivation on sleep and arousal characteristics of healthy infants (Franco et al., submitted). Thirteen healthy infants with a median age of 8 weeks (range 7–18 weeks) were recorded polygraphically during a morning nap and an afternoon nap in a sleep laboratory. They were two hours sleep-deprived, either in the morning or in the afternoon before being allowed to fall asleep. Six infants were sleep-deprived before the morning nap and seven before the afternoon nap. During each nap, the infants were exposed to white noises of increasing intensities in REM sleep to determine their arousal thresholds. Following sleep deprivation, the infants tended to have less gross body movements during sleep (p = .054). They had a significant increase in obstructive sleep apnoeas (p = .012). The infants' auditory arousal thresholds were significantly higher following sleep-deprivation (mean of 76+/-13.5 dB(A)) than during normal sleep (mean of 56+/-8.4 dB(A)) (p = .003) and during REM sleep. It was concluded that short-term sleep deprivation in infants is associated with the development of obstructive sleep apnoeas and a significant increase in arousal thresholds.

*Pacifiers and breastfeeding*

Fifty-six healthy infants were studied polygraphically during one night: 36 infants used a pacifier regularly during sleep; 20 never used a pacifier (Franco et al., 2000). Thumb users or occasional pacifier users were not included in the study. The infants were recorded at a median age of 10 weeks (range 6–19 weeks). To evaluate their auditory arousal thresholds, the infants were exposed to white noise of increasing intensity during REM sleep. Polygraphic arousals occurred at significantly lower auditory stimuli in pacifier-users than in nonusers (mean of 60+/-11.6 with pacifiers, for 71+/-15.3 without pacifier; p=.010). Compared to non-users, pacifier-users were more frequently bottle-fed than breastfed (p=.036).

Among infants sleeping without a pacifier, breastfed infants had lower auditory thresholds than bottle-fed infants (mean of 67.7+-13.0 breastfed, for 77.7+-17.5 bottle-fed; p=.049). The question of how a pacifier contributes to protect the sleeping infant might be best explained by the observed loss of the pacifier early after sleep onset. This could contribute to disruption of the infant's sleep and favour arousals.

## CONCLUSIONS

Various factors modify auditory arousal responses from sleep in healthy infants. Some inhibit arousals while others enhance the response. To evaluate the effect and dose-effect relationship on children therefore requires the careful determination of confounders that may bias studies and lead to conflicting results.

Additional confounders should be added to the list of factors that modify arousal thresholds. These include past experience with the stimulus (Rechtschaffen, Hauri and Zeitlin, 1966), or the presence of meaning in the noise as both of them are of critical importance in determining the persistence of physical reactions to the noise (McLean and Tarnopolsky, 1977). These are the reasons which lead most sleep/wake researchers to use white noises to stimulate the sleeping child.

Knowledge of these variables does little to clarify the physiological determinants of the awakening response, because knowledge of how such variables are related to possible physiological determinants is little better than that of the awakening response itself (Rechtschaffen, Hauri and Zeitlin, 1966).

These findings however, underline the significant dose–response relationship between ambient noise and arousal or awakening from sleep in infants.

# NOISE AND SLEEP FOR DIFFERENT STAGES OF DEVELOPMENT

## THE FETUS

The human fetus spends most of its time in a state equivalent to sleep, similar to that recorded in newborn infants. The healthy fetus in utero was shown to react to external noises. This is the result of the development of the human cochlea and peripheral sensory end organs. These complete their normal development by 24 weeks of gestation. Sound is well transmitted into the uterine environment. Ultrasonographic observations of blink/startle responses to vibroacoustic stimulation are first elicited at 24–25 weeks of gestation, and are consistently present after 28 weeks, indicating maturation of the auditory pathways of the central nervous system (Committee on Environment Health of the American Academy of Pediatrics, 1997). The fetus reacts to 1–4 seconds of 100–130 dB of 1220–15000 Hz sound. The hearing threshold (the intensity at which one perceives sound) at 27–29 weeks of gestation is approximately 40 dB and decreases to a nearly adult level of 13.5 dB by 42 weeks of gestation, indicating continuing postnatal maturation of these pathways.

Teratogenic effects have been described in animals prenatally exposed to noise (Committee on Environment Health of the American Academy of Pediatrics, 1997). These were associated with higher levels of cortisol and corticotropin hormones in the exposed animals. No such effects could be demonstrated in humans, in whom studies on the relation between exposure to noises during gestation and shortened gestation or lower birth weights were inconclusive or conflicting. It is possible that in these studies, noise could be a marker of other risk factors (Committee on Environment Health of the American Academy of Pediatrics, 1997). In conclusion, most studies on the effects of noise on perinatal health have been criticized as being hampered by serious methodological limitations, both in terms of the measurement of exposure and outcome, and failure to control for other known determinants of the outcomes under investigation. The lack of properly controlled studies makes it difficult to draw conclusions about what effects ambient noise has on perinatal outcomes (Morrell, Taylor and Lyle, 1997).

## NEWBORN INFANTS

A large number of investigations have been concerned with the responses of sleeping newborn infants to acoustic signals. Many of the studies arise from a large and general interest in child development as well as from a need for hearing tests for infants (Mills, 1975).

Infant incubators produce continuous noise levels of between 50 and 86 dB(lin) (American Academy of Pediatrics, 1974). Oxygen inlets produced an additional 2 dB (lin). Slamming of incubator doors and infant crying produced 90 to 100 dB(A)

(American Academy of Pediatrics, 1974). It was shown that inside incubators, background noise level is about 50 dBA and can reach 120 dBA (Committee on Environment Health of the American Academy of Pediatrics, 1997). Much of the energy is located below 500 Hz, between 31 and 250 Hz (Mills, 1975).

Ambient noise appears to influence the quantity and quality of the sleep of newborns. Some newborns appear to be particularly responsive to ambient noises. Sleeping premature, anoxic, or brain-damaged infants detect intruding sounds better than sleeping healthy or term babies (Mills, 1975).

Newborn infants spend most of their time sleeping. Some studies have documented hearing loss in children cared for in intensive care units (Commitee on Environment Health of the American Academy of Pediatrics, 1997). Noise and some ototoxic drugs act synergistically to produce pathological changes of the inner ears of experimental animals (neomycin, kanamycin, sodium salicylate). The relationship with the infant's clinical condition and associated treatments has, however, not yet been clearly defined. Infants exposed to sound levels of incubators are usually premature, on drugs and in very poor health. Moreover, the exposures are continuous. A weak infant could spend weeks sleeping in such a noise level without rest periods away from noise (Mills, 1975).

High noise levels may be associated with other types of responses. In young infants, sudden loud (of approximately 80 dB) environmental noise induced hypoxaemia.

Noise reduction was associated in neonates with increases in sleep time, in particular in quiet sleep (Committee on Environment Health of the American Academy of Pediatrics, 1997). It also resulted in fewer days of respiratory support and oxygen administration. Premature infants cared for with noise reduction had a better maturation of electroencephalograms.

A Committee on Environmental Health of the American Academy of Pediatrics (1997) concluded that high ambient noise in the neonatal intensive care unit (NICU) changed the behavioural and physiological responses of infants. For all the above observations and considerations, sound in infant intensive care units should be maintained at under 80 dB(A) (Graven, 2000). Among other recommendations, paediatricians were encouraged to monitor sound in the NICU, and within incubators, where a noise level greater than 45 dB is of concern.

## INFANTS (1 MONTH TO 1 YEAR OLD)

Some studies of the effect of external noises on the sleep/wake reactions of infants were conducted in their natural home environment. The reactions of babies to aircraft noise were studied by means of electroplethysmography (PLG) and EEG (Ando and Hattori, 1977). The recordings were done in the morning, in the infants' sleeping rooms. The infants were exposed to recorded noise of a Boeing 727 at take-off. The noise was presented at 70, 80 and 90 dB(A) at peak level at the position of the babies' heads. The subjects who had not been awakened by exposure to aircraft noise were exposed to music (Beethoven's Ninth Symphony) at levels of 70, 80 and 90 dB(A). The frequency ranged between 100 Hz and 10 kHz. It was found that the babies whose mothers had moved to the area around the Osaka International Airport before conception (Group I; n=33) or during the first five months of pregnancy (Group II; n=17) showed little or no reaction to aircraft noise. In contrast, babies whose mothers had moved closer to the airport during the second half of the pregnancy or after birth (Group III; n=10 or IV; n=3) and the babies whose mothers lived in a quiet living area (Group V; n=8) reacted to the same auditory stimuli. The babies in groups I and II showed differential responses depending on whether the auditory stimuli were aircraft noise or music. Abnormal PLG and EEG were observed in the majority of babies living in an area where noise levels were over 95 dB(A). It was concluded that the difference in reactivity to aircraft noise may be ascribed to a prenatal difference in time of exposure to aircraft noise. The reactions diminished after the sixth month of life in groups I and II, and the ninth month in groups III to V. This phenomenon may be explained as habituation to aircraft noise after birth. However, in all groups, no habituation occurred for a noise level over 95 dB(A) (Ando and Hattori, 1977). This study was criticized, as the authors did not adjust for several important determinants of birth weight, such as prematurity and the mother's age, weight, smoking status or socioeconomic status (Morrell et al., 1997).

Noise levels may be constantly high in paediatric units. The mean noise levels measured in a centre of a surgical recovery room were 57.2 dB(A), while those measured at the patients' heads were 65.6 dB(A) (American Academy of Pediatrics, 1974). In a medical unit (6-bed wards containing 5 infants between 3 and 17 months) peak sound levels were recorded on the pillow of the cot for 12 min (Keipert, 1985). Infant crying produced 75–90 dB(A) and a beeper around 76–78 dB(A). Peak noise levels recorded at the nurses' station were about 78 dB(A) for telephone, 80 for infant crying, public address system, adult talking, and up to 90 dB(A) for child talking (Keipert, 1985).

In a study conducted on infants exposed to 50–80 dB(lin) in the range of 100–7000 Hz (American Academy of Pediatrics, 1974), a level of 70–75 dB(lin) for 3 minutes led to obvious disturbance or awakening in two thirds of the children. All infants awakened after 75 dB(lin) for 12 minutes.

In other studies conducted on the effects of awakening and arousal, it was shown that white noise intensity was significantly lower when it elicited polygraphically scored arousals than when it induced awakenings (Franco et al., 1998).

## TODDLERS PREADOLESCENTS (8–12 YEARS OLD) ADOLESCENTS (13–18 YEARS OLD)

Developmental variations in auditory arousal thresholds during sleep were investigated in four groups of normal male subjects: children (n=6; 5–7 years old), preadolescents (n=10; 8–12 years old), adolescents (n=10; 13–16 years old), and young adults (n=10; 20–24 years old) (Busby, Mercier and Pivik, 1994). Arousal thresholds were determined during non-REM and REM sleep for tones (3-s, 1500 Hz pure tones delivered in an ascending series of increasing intensity, 5 dB increments beginning at 30 dB SPL (sound pressure level) re 0.0002 dynes/cm2 until awakening or maximum intensity of 120 dB) presented via earphone insert on a single night following two adaptation nights of undisturbed sleep. Age-related relationships were observed for both awakening frequency and stimulus intensity required to effect awakening, with awakenings occurring more frequently in response to lower stimulus intensities with increasing age. In children, 43.1% of stimuli induced awakenings, in preadolescents 54.8%, adolescents 72% and adults 100% (X2=60.37; p<.001). Partial arousals (brief EEG desynchronization and/or EMG activity with the subjects returning to sleep) occurred in 9.8% of children, 4.8% of preadoles-



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cents, 12.2% of adolescents, 0% of adults. Although stimulus intensities required for awakening were high and statistically equivalent across sleep stages in non-adults, higher intensity stimulus was required in stage 4 relative to stage 2 and REM sleep. Frequency of awakening increased with age, whereas stimulus intensities required to effect these awakenings decreased with age. These relationships were maintained for individual sleep stages. These results confirm previous observations of marked resistance to awakening during sleep in preadolescent children and suggest that processes underlying awakening from sleep undergo systematic modification during ontogenic development. The observed resistance to elicited awakening from sleep extending up to young adulthood implies the presence of an active, developmentally related process that maintains sleep (Busby, Mercier and Pivik, 1994).

In another study, children aged 5–7 years were shown to be 10–15 dB less sensitive to pure tones than adults aged 22–30 (Mills, 1975). Another report on male hyperactive and normal children aged 8–12 showed that these children were awakened with auditory stimulus intensity levels of up to 123 dB SPL, much higher than values reported for adults (range of 50–85 dB) (Busby, Mercier and Pivik, 1994).

In a study on four children (two males), aged 5–8 years old on the effects of simulated sonic booms (68 dB(A) near the subjects' ears), 94.1% of the subjects showed no change, 5.9% had shallower sleep, but none aroused or had behavioural awakening. In general, the frequency of arousal or behavioural awakenings and of sleep stage changes increased with age (up to 75 years) (Lukas, 1975).

In a prospective longitudinal investigation, which employed non-exposed control groups, effects of aircraft noise prior to and subsequent to inauguration of a new airport as well as effects of chronic noise and its reduction at an old airport (6–18 months after relocation), were studied in 326 children aged 9–13 years (Bullinger et al., 1999). The psychological health of children was investigated with a standardized quality of life scale as well as with a motivational measure. In addition, a self-report noise annoyance scale was used. In the children studied at the two airports over three time points, results showed a significant decrease of total quality of life 18 months after aircraft noise exposure as well as motivational deficits demonstrated by fewer attempts to solve insoluble puzzles in the new airport area. Parallel shifts in children's attributions for failure were also noted. At the old airport parallel impairments were present before the airport relocation but subsided thereafter (Bullinger et al., 1999).

In some studies, the effects of ambient noise on autonomic responses could be demonstrated in children. In children aged 6–12 years exposed to intermittent traffic noise during 4 nights (at a rate of 90 noises per hour; peak intensity of the noise, 45, 55 and 65 dB(A) varied semi-randomly) and 2 quiet nights. Heart rate was affected and relatively higher in noise during REM and stage 2 than during delta sleep (Muzet et al., 1980, in Abel, 1990).

## CONCLUSIONS

Several studies on the extra-auditory effects of ambient noise on sleeping children were summarized in Table 1. In relation to ambient noise, specific changes were reported in both sleep quality and quantity. Some of the effects were shown to have a dose–response relationship.
Several limitations to the present report should be discussed. Firstly, no one knows

whether the inference that is often made that the effects of noise might develop with a longer exposure time (Abel, 1990) is correct. Serious cardiorespiratory or autonomic changes, such as increases in BP could only develop following a long time exposure starting from childhood. This, in fact, has never been documented, nor has the extent of variability between subjects due to difference in susceptibility. Secondly, there is no information to evaluate whether adaptation to ambient noise could limit the effects observed during short-term experiments. Thirdly, as the existing research data are applicable to generally healthy children, no one knows how the reported findings could be applied to ill children, children receiving medical treatment or very young premature infants. Finally, as most studies were conducted in laboratory controlled environments, no one knows the correlation between these studies and the effects of noise in the home. The multifactorial effects of the environment on sleep and arousal controls could be much more complex than expected. One might predict that, similarly as for adults, the effects of noise on the child's sleep and health are very complicated and depend upon the spectrum and level of the noise, temporal aspects of the noise, psychological responses to the noise and the nature of the evaluation technique. The complexity of the conditions related to sleep/wake controls was illustrated by the review of confounding factors affecting auditory arousal thresholds.

Despite these limitations, it can be concluded that, based on the evidence available, the extra-auditory effects of noise could be pervasive, affecting the children's physical and psychological well-being. Changes in sleep quantity and quality together with autonomic reactions are seen when a child is exposed to ambient noise during sleep. Ambient noise exerts a dose-effect relationship on changes in sleep/wake behaviours. These reflect modifications induced within the brain of the sleeping child. It remains, however, to be determined what pervasive effects long-term exposure to ambient noise has on the child's development, health and well-being. Evidence should also be defined to support an enforcement of strategies for noise reduction at the source as suggested by some studies. Noise-induced health effects on children, a clinical and public health concern, should be evaluated by further studies.

**Table 1**
**Arousal and awakening in children a review of the literature**

| No. | dB(A) | % responses | Type of responses | Reference |
|---|---|---|---|---|
| 1 | 80 | 70 | Nenonates motor response | Steinschneider 1967 |
| 2 | 60 | 5 | Neonates startle response | Gädeke et al.,1969 |
| 70 | 10 | | | |
| 80 | 20 | | | |
| 100 | 60 | | | |
| 3 | 60 | 7 | Neonates startle response | Ashton 1967 |
| 65 | 10 | | | |
| 70 | 40 | | | |
| 4 | 80 | 70 | Child awake | Semczuk 1967 |
| 5 | 100 | 70 | Child awake | Busby, Mercier and Pivik 1994 |
| 6 | 100 | 76 | Preadolescent awake | |
| 7 | 100 | 86 | Adolescent awake | |
| 8 | 60 | 100 | Adult | |
| 9 | 120 | 72 | Infant awake | Kahn, Picard and Blum, 1986 |
| 10 | 75 | 75 | Infant awake | Gädeke et al., 1969 |

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**The WHO Regional Office for Europe**

The World Health Organization (WHO) is a specialized agency of the United Nations created in 1948 with the primary responsibility for international health matters and public health. The WHO Regional Office for Europe is one of six regional offices throughout the world, each with its own programme geared to the particular health conditions of the countries it serves.

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Environmental noise is a threat to public health, having negative impacts on human health and wellbeing. This book reviews the health effects of night time noise exposure, examines dose effects relations, and presents interim and ultimate guideline values of night noise exposure. It offers guidance to policy-makers in reducing the health impacts of night noise, based on expert evaluation of scientific evidence in Europe.

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**Regional Office for Europe**

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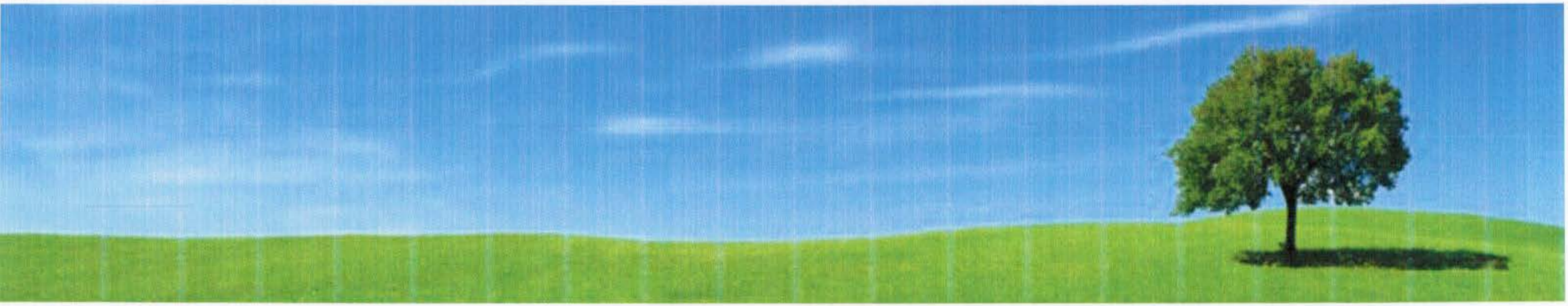

# Wind Turbines
# Do They Cause Health Problems?


**Christopher Ollson, Ph.D.**
Intrinsik Environmental Sciences, Inc.
Mississauga, ON, Canada
collson@intrinsik.com


EXHIBIT
I 10

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# Intrinsik's Renewable Energy Health Team

- Health scientists dedicated to research and consultation in health aspects of renewable energy

Dr. Christopher Ollson, Ph.D. (co-leader)

Dr. Loren Knopper, Ph.D. (co-leader)

Dr. Melissa Whitfield Aslund, Ph.D.

Ms. Lindsay McCallum, M.Env.Sci. (Ph.D. Cand)

Dr. Mary McDaniel, DO, JD, MPH

Dr. Robert Berger, Ph.D.

**Review** Highly accessed Open Access

**Health effects and wind turbines: A review of the literature**

**Loren D Knopper**[1*] and **Christopher A Ollson**[2]

McCallum *et al. Environmental Health* 2014, **13**:9
http://www.ehjournal.net/content/13/1/9

ENVIRONMENTAL HEALTH

**RESEARCH** **Open Access**

Measuring electromagnetic fields (EMF) around wind turbines in Canada: is there a human health concern?

Lindsay C McCallum[1,2], Melissa L Whitfield Aslund[2], Loren D Knopper[2], Glenn M Ferguson[2] and Christopher A Ollson[2*]

Energy Policy 62 (2013) 44–50

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Contents lists available at ScienceDirect

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ENERGY POLICY

CrossMark

Projected contributions of future wind farm development to community noise and annoyance levels in Ontario, Canada

Melissa L. Whitfield Aslund, Christopher A. Ollson, Loren D. Knopper*

Noise & Health

A Bi-monthly Inter-disciplinary International Journal
www.noiseandhealth.org

Letter to Editor: Are the findings of "Effects of industrial wind turbine noise on sleep and health" supported?

Christopher A. Ollson,
Loren D. Knopper, Lindsay C. McCallum,
Melissa L. Whitfield-Aslund

006749

*Noise & Health, March-April 2013, Volume 15:63, 148-52*

# The Issue

- Public generally favours the idea of wind energy.



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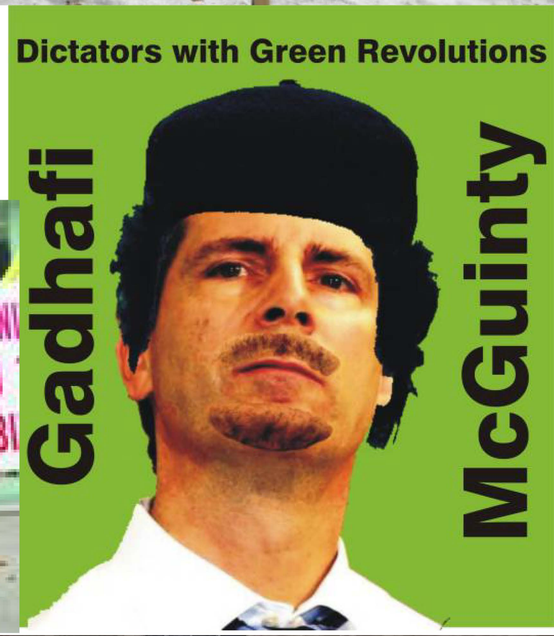
Note to Aust. Med. Assoc.
"First, do no harm!"


WHEN THE SCIENCE OF WIND ENERGY TURNS INTO THE ART OF PROSTITUTION (EDITORIAL)
Mar 1, 2014


LIBERALS SILENCE RURAL ONTARIO
RESTORE DEMOCRACY


Dictators with Green Revolutions
Gadhafi
McGuinty


OUR COMMUNITY SAYS NO TO WIND TURBINES


THE F.I.T IS GONNA HIT THE FAN
WIND TURBINES DEVALUE HOMES
STOP
NO TO WHITE PINES
SOUTHMARYSBURGH
PLANT TREES NOT TURBINES!

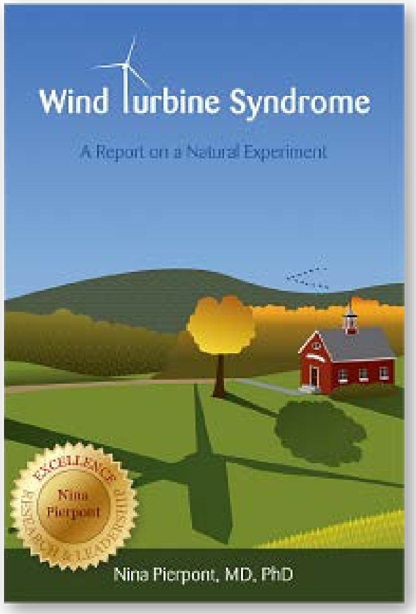

SAY NO AND PROTEST


NOT A WILLING HOST!

006751

# Wind Turbine Syndrome

- Self-reported symptoms generally included:
  - Annoyance, sleep disturbance, tiredness, headache, tinnitus, irritability, nausea, lack of concentration.
- This collection of effects is commonly called "Wind Turbine Syndrome" (Pierpont, 2009).
- The reason for the self-reported health effects is highly debated.

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# Noise and Health

- Environmental noise above certain levels is a recognized factor in a number of human health issues
  – e.g., hearing, sleep, myocardial infarction, annoyance
- Noise from wind turbines can be annoying to some and associated with sleep disturbance
  – especially when found at levels greater than 40 dB(A)
  – WHO (EU) night noise guideline
- Proper siting of wind turbines is key!
  – Even when noise limits are enforced it is possible that a segment of the population may remain annoyed (or report other health impacts)

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# Human Health – The Debate

**Health effects related to wind turbine operation***

- Audible noise
- Low frequency noise
- Infrasound
- Shadow flicker

*often regardless of regulated setbacks

**Health effects related to subjective issues***

- Attitude
- Visual cue
- Stress
- Expectations
- Economics.

*based on proper noise setbacks

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# Weight of Scientific Evidence from ~60 Peer-Reviewed Articles

1. People tend to notice sound from wind turbines almost linearly with increasing sound pressure level

ORIGINAL ARTICLE

# Wind turbine noise, annoyance and self-reported health and well-being in different living environments

**Eja Pedersen, Kerstin Persson Waye**

*Occup Environ Med* 2007;**64**:480–486. doi: 10.1136/oem.2006.031039

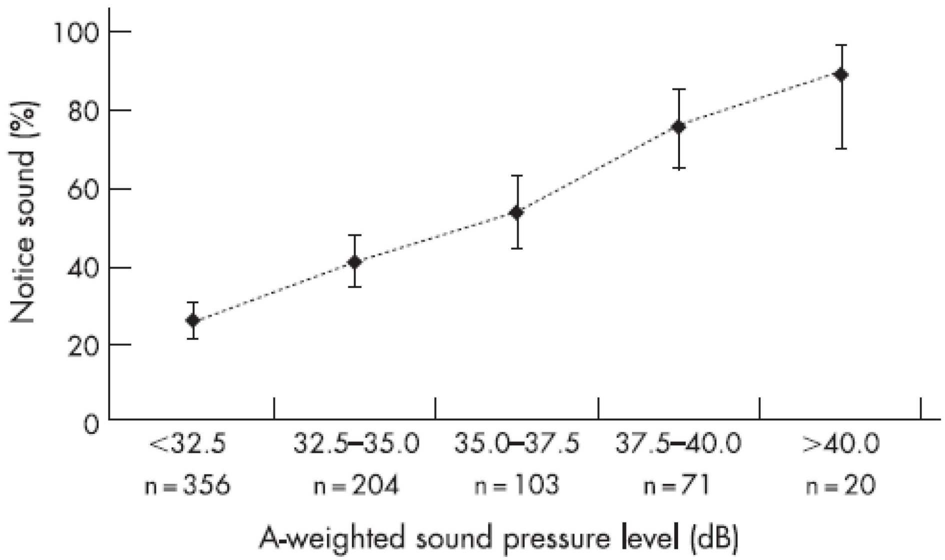


**Figure 1** Proportion of respondents who noticed sound from wind turbines outside their dwelling, in relation to A-weighted sound pressure levels in 2.5-dB intervals. Vertical bars indicate 95% confidence intervals; n, the total number of respondents in each interval.

006756

# Weight of Scientific Evidence

1. People tend to notice sound from wind turbines almost linearly with increasing sound pressure level

2. A proportion of people that notice sound from wind turbines find it annoying

# A comparison between exposure-response relationships for wind turbine annoyance and annoyance due to other noise sources

Sabine A. Janssen[a)] and Henk Vos
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Arno R. Eisses
*Department of Acoustics and Sonar, Netherlands Organization for Applied Scientific Research, P.O. Box 96864, 2509 JG The Hague, The Netherlands*

J. Acoust. Soc. Am. **130** (6), December 2011

Eja Pedersen[b)]
*Ecology and Environmental Science, Halmstad University, P.O. Box 823, SE-301 18 Halmstad, Sweden*

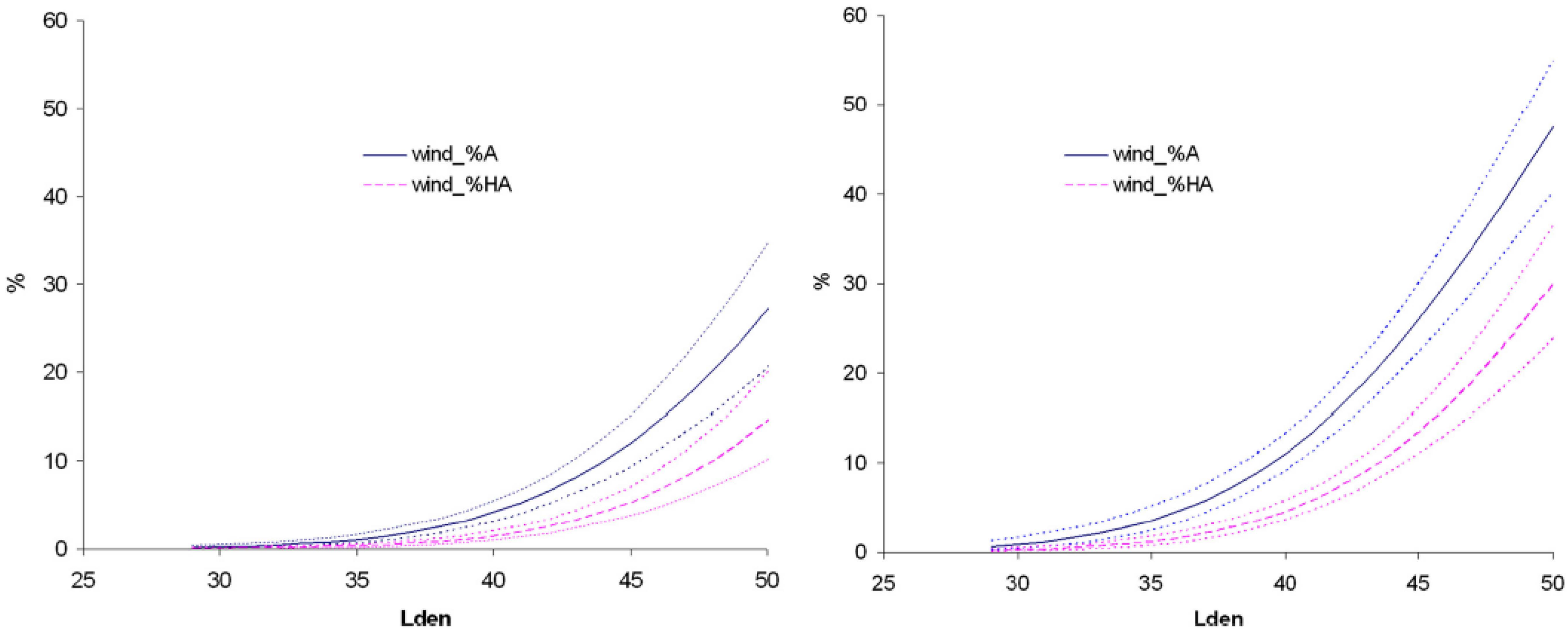


FIG. 1. (Color online) The exposure-response relationships between $L_{den}$ and the percentage of residents annoyed (%*A*) and highly annoyed (%*HA*) indoors (left) and outdoors (right).

# Weight of Scientific Evidence

1. People tend to notice sound from wind turbines almost linearly with increasing sound pressure level

2. A proportion of people that notice sound from wind turbines find it annoying

3. Noise-related annoyance from turbines can be within the range of existing levels of community noise related annoyance

# Impact of Wind Turbine Noise in The Netherlands

Verheijen, E., Jabben, J., Schreurs, E., Smith, K.B
Noise & Health, November-December 2011, Volume 13:55, 459-63

National Institute for Public Health
and the Environment
*Ministry of Health, Welfare and Sport*

- "*The percentage of severely annoyed at 45 dB* [Lden] *is rated at 5.2% for wind turbine noise, which is well below 10% that corresponds to the existing road and railway traffic noise limits".*

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# Weight of Scientific Evidence

1. People tend to notice sound from wind turbines almost linearly with increasing sound pressure level

2. A proportion of people that notice sound from wind turbines find it annoying

3. Noise-related annoyance can be within the range of existing levels of community noise related annoyance

4. People who economically benefit from wind turbines have significantly decreased levels of annoyance compared to individuals that received no economic benefit

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Science of the Total Environment 425 (2012) 42–51

Contents lists available at SciVerse ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

# Impact of wind turbine sound on annoyance, self-reported sleep disturbance and psychological distress

R.H. Bakker [a,*], E. Pedersen [b], G.P. van den Berg [c], R.E. Stewart [d], W. Lok [a,1], J. Bouma [e]

**Table 4**
Response to indoor wind turbine sound among economically benefitting and non-benefitting respondents.

| | Response | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Do not notice | | Notice, not annoyed | | Slightly annoyed | | Rather annoyed | | Very annoyed | | Total | |
| | n | % | n | % | n | % | n | % | n | % | n | % |
| No economical benefit | 394 | 68 | 98 | 17 | 46 | 8 | 21 | 4 | 20 | 4 | 579 | 100 |
| Economical benefit | 53 | 54 | 39 | 39 | 7 | 7 | 0 | 0 | 0 | 0 | 99 | 100 |

**Table 7**
Sound sources of sleep disturbance in rural and urban area types, only respondents who did not benefit economically from wind turbines.

| Sound source of sleep disturbance | Rural | | Urban | | Total | |
|---|---|---|---|---|---|---|
| | n | % | n | % | n | % |
| Not disturbed | 196 | 69.8 | 288 | 64.9 | 484 | 66.8 |
| Disturbed by people/ animals | 33 | 11.7 | 64 | 14.4 | 97 | 13.4 |
| Disturbed by traffic/ mechanical sounds | 35 | 12.5 | 75 | 16.9 | 110 | 15.2 |
| Disturbed by wind turbines | 17 | 6.0 | 17 | 3.8 | 34 | 4.7 |
| Total | 281 | 100 | 444 | 100 | 725 | 100 |

# Weight of Scientific Evidence

1. People tend to notice sound from wind turbines almost linearly with increasing sound pressure level
2. A proportion of people that notice sound from wind turbines find it annoying
3. Noise-related annoyance can be within the range of existing levels of community noise related annoyance
4. People who economically benefit from wind turbines have significantly decreased levels of annoyance compared to individuals that received no economic benefit
5. Annoyance is not only related to wind turbine noise but also to subjective factors like attitude, visual cue, stress and expectations

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# Perception and annoyance due to wind turbine noise—a dose–response relationship

Eja Pedersen[a] and Kerstin Persson Waye

J. Acoust. Soc. Am. **116** (6), December 2004

Health Psychology

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0278-6133/13/$12.00 http://dx.doi.org/10.1037/a0031760

# Can Expectations Produce Symptoms From Infrasound Associated With Wind Turbines?

Fiona Crichton, George Dodd, Gian Schmid, Greg Gamble, and Keith J. Petrie
University of Auckland

Health Psychol. 2013 Nov 25. [Epub ahead of print]

# The Power of Positive and Negative Expectations to Influence Reported Symptoms and Mood During Exposure to Wind Farm Sound.

Crichton F, Dodd G, Schmid G, Gamble G, Cundy T, Petrie KJ.

# The Effects of Vision-Related Aspects on Noise Perception of Wind Turbines in Quiet Areas

Luigi Maffei [1,*], Tina Iachini [2], Massimiliano Masullo [1], Francesco Aletta [1], Francesco Sorrentino [1], Vincenzo Paolo Senese [2] and Francesco Ruotolo [2]

*Int. J. Environ. Res. Public Health* **2013**, *10*

OPEN ACCESS Freely available online

PLOS | ONE

# The Pattern of Complaints about Australian Wind Farms Does Not Match the Establishment and Distribution of Turbines: Support for the Psychogenic, 'Communicated Disease' Hypothesis

Simon Chapman*, Alexis St. George, Karen Waller, Vince Cakic
Sydney School of Public Health, University of Sydney, New South Wales, Australia

006764

# MEASUREMENT AND LEVEL OF INFRASOUND FROM WIND FARMS AND OTHER SOURCES

Chris Turnbull, Jason Turner and Daniel Walsh

Acoustics Australia Vol. 40, No. 1, April 2012 - 45

- Infrasound is prevalent in urban and coastal environments at similar (or greater) levels to the level of infrasound measured close to a wind turbine.

Table 2. Measured levels of infrasound

| Noise Source | Measured Level (dB(G)) |
|---|---|
| Clements Gap Wind Farm at 85m | 72 |
| Clements Gap Wind Farm at 185m | 67 |
| Clements Gap Wind Farm at 360m | 61 |
| Cape Bridgewater Wind Farm at 100m | 66 |
| Cape Bridgewater Wind Farm at 200m | 63 |
| Cape Bridgewater Wind Farm ambient | 62 |
| Beach at 25m from high water line | 75 |
| 250m from coastal cliff face | 69 |
| 8km inland from coast | 57 |
| Gas fired power station at 350m | 74 |
| Adelaide CBD at least 70m from any major road | 76 |

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# Weight of Scientific Evidence

- Based on the findings and scientific merit of the available studies, the weight of evidence suggests that when sited properly, wind turbines are not related to adverse health effects

- Government findings
  - National Health and Medical Research Council in Australia, 2010
  - Chief Medical Officer of Health (ON), May 2010
  - MassDEP and MDPH, 2012
  - Oregon Health Authority, 2013
  - National Health and Medical Research Council in Australia, 2014

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# Intrinsik's Health Based Siting Recommendations

1. Setbacks should be sound-based rather than distance-based alone.

2. Preference should be given to sound emissions of ≤40 dBA (outside, not including ambient) for non-participating individuals.

3. Post construction monitoring should be common place to ensure actual sound levels are within required noise limits.

4. If sound emissions from wind projects in the 40-45 dB(A) range for non-participating individuals, we suggest community consultation and community support.

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# Intrinsik's Health Based Siting Recommendations

5. Setbacks of >45 dB(A) (wind turbine noise only; not including ambient noise) for non-participating individuals directly outside a dwelling are not supported due to possible direct effects from audibility and possible levels of annoyance above background.

6. When ambient noise is taken into account, wind turbine noise can be >45 dB(A), but a combined wind turbine-ambient noise should not exceed >55 dB(A) for non-participating and participating individuals.

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# Red Lily Legal Challenge

QUEEN'S BENCH FOR SASKATCHEWAN

Citation: **2010 SKQB 374**

Date: **2010 10 07**
Docket: Q.B.G. No. 1251 of 2010
Judicial Centre: Saskatoon

---

BETWEEN:

DAVID McKINNON

PLAINTIFF

- and -

THE RURAL MUNICIPALITY OF MARTIN NO. 122, and THE RURAL MUNICIPALITY OF MOOSOMIN NO. 121, RED LILY WIND ENERGY CORP. and 7314507 CANADA INC., operating as a general partnership known as RED LILY WIND ENERGY PARTNERSHIP

DEFENDANTS



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# Alberta AUC Rule 012 Upheld

## Bull Creek wind project approved by Alberta Utilities Commision

Story | Comments | Image (1) — Share | Print | Font Size:

Tweet 1 | Like 0

Posted: Friday, February 28, 2014 12:06 pm

**Kelly Clemmer, Editor-in-Chief | 0 comments**

The Alberta Utilities Commission have approved the application to build the BluEarth Renewable's Bull Creek Wind Project, February 20, 2014, at the south border of the MD of Wainwright and northern border of the MD of Provost.

"All of the councillors were pleased with the end result," said Jim Klasson, the MD of Wainwright's development officer. "Council and admin supported the project.

"It can't be overlooked that the rest of the province knows that we're open for business," said Klasson.

The Bull Creek wind energy project was applied for in June, 2012, and after a number of steps in the process, the Killarney Lake Group (KLG) opposed the project. AUC held public hearings on October 28, 2013 to November 1, 2013 in Provost. The hearing resumed in Calgary from November 18 to 22. It was from that hearing that AUC made its decision, that the Bull Creek project was "in the public's interest."

BluEarth RENEWABLES INC.

AUC Alberta Utilities Commission

**1646658 Alberta Ltd.**

**Bull Creek Wind Project**

**February 20, 2014**

# Thank you

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**Environment and Land Tribunals Ontario**

☒ Environmental Review Tribunal
☐ Niagara Escarpment Hearing Office
☐ Office of Consolidated Hearings

## Acknowledgement of Expert's Duty

| Case Name and No.: | 14-065 / 14-066-14-067 |
|---|---|

1. My name is CHRISTOPHER OLSON (name). I live at Ancaster (city) in the province (province/state) of Ontario (name of province/state).
2. I have been engaged by or on behalf of Stincor (name of party/parties) to provide evidence in relation to the above-noted proceeding.
3. I acknowledge that it is my duty to provide evidence in relation to this proceeding as follows:

   (a) to provide opinion evidence that is fair, objective and non-partisan;

   (b) to provide opinion evidence that is related only to matters that are within my area of expertise;

   (c) to provide opinion evidence in accordance with the Environmental Review Tribunal's Practice Direction for Technical and Opinion Evidence; and

   (d) to provide such additional assistance as the tribunal may reasonably require, to determine a matter in issue.

4. I acknowledge that the duty referred to above prevails over any obligation which I may owe to any party by whom or on whose behalf I am engaged.

Date 23 Oct 2014

Signature

*Appendix F: Form 5*



EXHIBIT I9A

006772

Case No. 14-065/14-066-14-067

In the matter of appeals by The Corporation of the County of Lambton ("County") filed September 4, 2014 and Kimberley and Richard Lance Bryce ("Bryces") filed September 5, 2014 for a Hearing before the Environmental Review Tribunal ("Tribunal") pursuant to section 142.1 of the *Environmental Protection Act*, R.S.O. 1990, c. E.19, as amended ("EPA"), with respect to Renewable Energy Approval No. 6914-9L5JBB issued by the Director, Ministry of the Environment, on August 22, 2014 to Suncor Energy Products Inc. ("Suncor"), under section 47.5 of the *Environmental Protection Act*, regarding a Class 4 wind facility consisting of the construction, installation, operation, use and retiring of a wind facility with a total nameplate capacity of 100 megawatts (MW) ("Cedar Point"), with the substation located at the Southwest corner of Cedar Point Line and Fuller Road, in the Municipality of Lambton Shores and other project infrastructure at various locations within the Town of Plympton-Wyoming, Municipality of Lambton Shores, Warwick Township, and Lambton County, Ontario.

**WITNESS STATEMENT**

**OF**

**Christopher Andrew Ollson, Ph.D.**
**Vice President**
**Senior Environmental Health Scientist**
**Intrinsik Environmental Sciences Inc.**
**6605 Hurontario Street**
**Mississauga, Ontario**

## INTRODUCTION

1. I have no personal interest in the outcome of this appeal. I intend to appear before the Environmental Review Tribunal (ERT) and be subject to direct examination and cross-examination. My evidence will be factual and opinion evidence. I have read the ERT's Practice Direction for Technical and Opinion Evidence and I provide this statement in accordance with that Practice Direction. Attached as **Exhibit "1"** to this witness statement is a Form 5 that I signed in accordance with the ERT's Rules of Practice.



EXHIBIT
tabbies
I9B

## AREA OF EXPERTISE

2. My area of expertise is in the field of environmental health science. I am trained, schooled and practiced in the evaluation of potential risks and health effects to people and ecosystems associated with environmental issues.

3. I have been qualified to provide opinion evidence on wind turbines and potential health effects at three previous ERTs (Erickson v. MOE 2011; Monture v. MOE [GREP] 2012; and Moseley v. MOE 2014). In addition, I provided expert evidence with regard to wind turbines and health for the Queen's Bench of Saskatchewan in McKinnon v. Martin (2010 – also referred to as the Red Lily case) and at the Alberta Utilities Commission (AUC) Proceeding No. 1955, Bull Creek Wind Project (October 2013). I am also under contract to provide expert advice on wind turbines, health and proper siting requirements for the Vermont Public Services Department.

## POSITION AND QUALIFICATIONS

4. I am the Vice President, Strategic Development and Senior Environmental Health Scientist at Intrinsik Environmental Sciences Inc. ("Intrinsik"). A copy of my current *curriculum vitae* is attached as **Exhibit 2** to this witness statement. I am recognized across Canada by the federal and provincial/territorial governments, including the province of Ontario, as a senior environmental health scientist, risk assessor and environmental toxicologist.

5. My formal education includes:

   a. Doctorate of Philosophy, Environmental Science, Royal Military College of Canada, Kingston, Ontario, 2003.

   b. Master of Science, Environmental Science, Royal Military College of Canada, Kingston, Ontario, 2000.

   c. Bachelor of Science (Honours), Biology, Queen's University, Kingston, Ontario, 1995.

6. I hold an appointment of Adjunct Assistant Professor at the Royal Military College of Canada in the Department of Chemistry and Chemical Engineering and Adjunct Professor in the School of the Environment at the University of Toronto. My duties include teaching of graduate level courses in Environmental Risk Assessment and co-supervision of graduate students. I have also supervised a number of Natural Sciences and Engineering Research Council (NSERC) Industrial Post-Doctoral Fellows over the past decade, including two that have published in the area of wind turbines and health. In 2013, I was appointed to the Governing Council and am Vice-Chair of the Academic Affairs Committee of the University of Toronto Scarborough Campus.

7. Over the past five years, I have been engaged by a number of private companies to review the potential health effects that may be associated with living in proximity to wind turbines as part of their preparation of environmental assessment documentation. This has led to the development of an Intrinsik research team comprised of three Doctoral level and one Master level (now Doctoral Candidate) staff members. Approximately one third of our practice on an annual basis has been devoted to better understanding the relationship between people and wind energy.

These research efforts were first published in a peer-reviewed scientific article entitled:

> Knopper, L.D. and **Ollson, C.A.** 2011. Health Effects and Wind Turbines: A Review of the Literature. Environmental Health. 10:78. Open Access. Highly Accessed.

Environmental Health is an open access journal (meaning anyone can obtain a copy for free) and has an impact factor of 2.71, meaning that articles published in this journal are often cited in other papers. After its publication in September 2011 the journal quickly identified the article as “highly accessed”, it has been viewed over 30,000 times and cited in more than 30 other scientific articles.

8. Subsequently, our research team has published the following articles.
Four articles in peer-reviewed scientific journals:

> **Ollson, C.A.**, Knopper L.D. McCallum, L.C., Aslund-Whitfield, M.L. 2013. Are the findings of ‘Effects of industrial wind turbine noise on sleep and health’ supported? Noise & Health 15:63, 148-150.

> Whitfield Aslund, M.L., **Ollson, C.A.,** Knopper, L.D. 2013. Projected contributions of future wind farm development to community noise and annoyance levels in Ontario, Canada. Energy Policy. 62, 44-50

> McCallum, L., Whitfield Aslund, M., Knopper, L.D., Ferguson, G.M. and **Ollson, C.A.** 2014. An investigation of wind energy and health: quantifying electromagnetic fields around wind turbines in Canada. *Environmental Health* 2014, **13**:9

> Knopper, L.D., Ollson, C.A., McCallum, L.C., Aslund, M.L., Berger, R.G, Souweine, K., and McDaniel, M. 2014. Wind turbines and Human Health. Front. Public Health, 19 June 2014 (attached as **Exhibit 3**)

Two additional conference proceeding publications for the 5th International Conference on Wind Turbine Noise, Denver, August 2013:

Whitfield Aslund, M.L., **Ollson, C.A.**, Knopper, L.D. 2013. 'Projected contributions of future wind farm development to community noise and annoyance levels in Ontario, Canada', submitted for publication in *Proceedings of the 5th International Conference on Wind Turbine Noise, Denver Colorado 28-30 August 2013*

Knopper, L.D., Whitfield Aslund, M.L., McCallum, L.C., **Ollson, C.A.** 2013. 'Wind turbine noise: What has the Science Told Us?', , submitted for publication in *Proceedings of the 5th International Conference on Wind Turbine Noise, Denver Colorado 28-30 August 2013*

**CHRONOLOGY OF INVOLVEMENT AND DOCUMENTS REVIEWED**

9. I was contacted by Counsel for Suncor in September, 2014 and asked to provide an opinion in this matter.

10. Intrinsik was retained by Suncor in 2012 to provide expertise and information on the current scientific and government literature related to wind turbines and health matters. I appeared at a number of open houses and community engagement events related to the project.

11. I have reviewed the following Appellant's documents:

    a. Notice of Appeal, dated September 5, 2014

    b. Disclosure Statement of the Appellants Richard Lance and Kimberley Bryce

    c. Witness Statement of Barbara Ashbee, unddated for ERT Case Nos. 13-084 to 13-089

    d. Witness Statement of Sandy MacLoed, undated for ERT Case Nos. 13-084 to 13-089

    e. Transcripts of Barbara Ashbee and Sandy MacLoed, September 24, 2013 for ERT Case Nos. 13-084 to 13-089

12. I also reviewed the Final Renewable Energy Approval and Reports provided on the Suncor Cedar Point Wind Power Project website at http://www.suncor.com/en/about/4797.aspx

    a. The most pertinent of the reports to my evidence was the noise report:
       Noise Assessment Report Cedar Point Wind Power Project. May 14, 2014. Prepared by HGC Engineering for Suncor Energy Projects

13. I have also attached "Knopper, L.D., Ollson, C.A., McCallum, L.C., Aslund, M.L., Berger, R.G, Souweine, K., and McDaniel, M. 2014. Wind turbines and Human Health. Front. Public Health, 19

June 2014” as **Exhibit 3** and have relied on this paper and the references it contains, in part, to form my opinion.

**DISCUSSION**

14. In my witness statement prepared for *Erickson v. Ontario Ministry of the Environment, January 17, 2011,* I provided the following statement:

> *“Through my review of the peer-reviewed, published scientific literature and government agency reviews, it is my professional opinion that the O. Reg. 359/09 requirements of <40 dB(A) and a minimum separation distance of 550 m between wind turbines and receptors is reasonable and sufficient to protect against adverse health effects.”*

Although there have been a number of government documents and scientific, social science and white papers published since *Erickson*, my review of this information has not changed my professional opinion from January 2011.

15. In the years following the publication of Knopper and Ollson (2011), the debate surrounding the relationship between wind turbines and human health has continued. As of June 2014, there were roughly 60 scientific peer-reviewed articles on the issue of causation between wind turbines and alleged health effects. While some argue that reported health effects are related to wind turbine operation (electromagnetic fields (EMF), shadow flicker, audible noise, low frequency noise, infrasound) others suggest that when turbines are sited correctly, effects are more likely attributable to a number of subjective variables (i.e., attitudes, expectation, visual aesthetics, economics) that result in an annoyed/stressed state. There is also a growing body of research that suggests that nocebo effects (that is where the etiology of the self-reported effect is in beliefs and expectations rather than a physiologically harmful entity) play a role in a number of self-reported health impacts related to the presence of wind turbines. Indeed negative attitudes and worries of individuals about perceived environmental risks have been shown to be associated with adverse health-related symptoms such as headache, nausea, dizziness, agitation and depression, even in the absence of an identifiable cause.

16. In 2014, colleagues and I published another peer-reviewed article where we critically evaluated these studies (see, Knopper, LD, et al., Wind Turbines and Human Health, 2014, *Frontiers in Public Health, vol. 2, art. 63,* copy attached as **Exhibit 3**). Based on the findings and scientific merit of the research conducted to date, it is my opinion that the weight of evidence suggests that when sited properly, wind turbines are not related to adverse health effects. This claim is supported (and has also been made) by findings from a number of government health and medical agencies (e.g., National Health and Medical Research Council in Australia, 2010; Chief

Medical Officer of Health (Ontario), May 2010; Massachusetts Department of Environmental Protection (MassDEP) and Massachusetts Department of Public Health (MDPH), 2012; Oregon Health Authority, 2013; National Health and Medical Research Council in Australia (Merlin et al., 2014)).

17. Based on the available evidence, and taken directly from Knopper et al. 2014, our research team has suggested the following best practices for wind turbine development in the context of human health. However, it should be noted that subjective variables (e.g., attitudes and expectations) are strongly linked to annoyance and have the potential to facilitate other health complaints via the nocebo effect. Therefore, it is possible that a segment of the population may remain annoyed (or report other health impacts) even when noise limits are enforced.

a. Setbacks should be sound-based rather than distance-based alone

b. Preference should be given to sound emissions of ≤40 dB(A) for non-participating receptors, measured outside, at a dwelling, and not including ambient noise. This value is the same as the WHO (Europe) night noise guideline (WHO, 2009) and has been demonstrated to result in levels of wind turbine community annoyance similar to, or lower than, known background levels of noise-related annoyance from other common noise sources.

c. Post construction monitoring should be common place to ensure modelled sound levels are within required noise limits.

d. If sound emissions from wind projects is in the 40-45 dB(A) range for non-participating receptors, we suggest community consultation and community support.

e. Setbacks that permit sound levels >45 dB(A) (wind turbine noise only; not including ambient noise) for non-participating receptors directly outside a dwelling are not supported due to possible direct effects from audibility and possible levels of annoyance above background.

f. When ambient noise is taken into account, wind turbine noise can be >45 dB(A), but a combined wind turbine-ambient noise should not exceed >55 dB(A) for non-participating and participating receptors. Our suggested upper limit is based on WHO (2009) conclusions that noise above 55 dB(A) is "*considered increasingly dangerous for public health*", is when "*adverse health effects occur frequently, a sizeable proportion of the population is highly annoyed and sleep-disturbed*" and "*cardiovascular effects become the major public health concern, which are likely to be less dependent on the nature of the noise*".

18. In addition, there has been recent speculation that low frequency noise or infrasound emitted from wind turbines could be the cause of health concerns reported by some living in proximity to wind projects. To that end, our research team along with Mr. Payam Ashtiani of Aercoustics Engineering Ltd. and Dr. Geoff Leventhall recently submitted a paper for review entitled "Health-based Audible Noise Guidelines Account for Infrasound and Low Frequency Noise Produced by Wind Turbines" to the *International Journal of Environmental Research in Public Health.*

    a. The purpose of this paper was to investigate whether current audible noise-based guidelines for wind turbines account for the protection of human health given the levels of infrasound (IS) and low frequency noise (LFN) typically produced by wind turbines. New field measurements of indoor IS and outdoor LFN at locations between 400 m and 900 m from the nearest turbine, which were previously underrepresented in the scientific literature, are reported and put into context with existing published works. Our analysis showed that indoor IS levels were below auditory threshold levels while LFN levels at distances >500 m were similar to background LFN levels. Collectively, these data in conjunction with previous reports indicate that levels of IS and LFN are not sufficient to induce adverse health effects; therefore health-based audible noise guidelines, as provided by the MOE, are suitable for the protection of human health.

19. A recent article that was not addressed in Knopper et al. (2014) is that of Dr. Ian Arra of Laurentian University and reported on the Cureus website in 2014*. Arra I, Lynn H, Barker K, et al. (2014-05-23 11:51:41 UTC) Systematic Review 2013: Association Between Wind Turbines and Human Distress. Cureus 6(5): e183. doi:10.7759/cureus.183.* Dr. Arra worked with Dr. Lynn in an attempt to provide a literature review of the issues surrounding wind turbines and health. This work in large part formed the basis for a Grey Bruce Board of Health Presentation given by Dr. Arra and Dr. Lynn on February 22, 2013. It is my opinion that Arra et al., 2014, should not be given any weight in this scientific debate and is not an authoritative review of the potential health effects associated with living in proximity to wind turbines. The paper contains numerous methodological and interpretation issues, and Cureus is not a reputable or indexed scientific or medical journal.

**CONCLUSION(S)**

20. During my review of the Suncor Cedar Point Wind Power Project documentation there was nothing that I noted that was unique or site-specific about this project that changes my professional opinion from January 2011.

21. I have reviewed the witness statements of Barbara Ashbee and Sandy MacLeod prepared for ERT Case Nos. 13-084 to 13-089. There is nothing contained within their statements or the accompanying transcripts, dated September 24, 2013, that would cause me to alter my opinion that the Cedar Point Wind Project will not cause serious harm to health.

22. Therefore, I will provide my professional opinion that the operation of the Suncor Cedar Point Wind Power Project, in accordance with the Renewable Energy Approval as issued, will not cause serious harm to human health.

23. I will also address any evidence raised by the Appellants or their witnesses regarding wind turbines and health effects.

| | |
|---|---|
| 23 October 2014 | |
| **DATE** | **Christopher Ollson, Ph.D.** |

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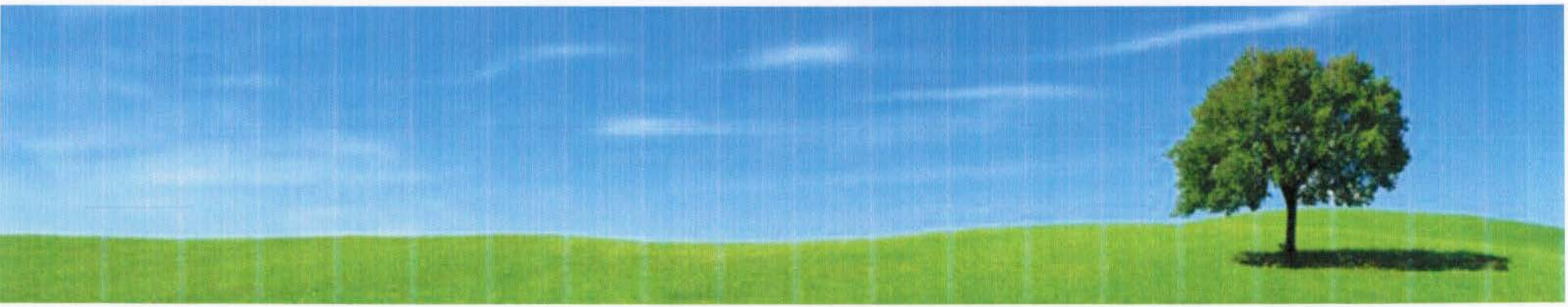

# Wind Turbines
# Do They Cause Health Problems?

**Christopher Ollson, Ph.D.**
Intrinsik Environmental Sciences, Inc.
Mississauga, ON, Canada
collson@intrinsik.com

EXHIBIT
I 10

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# Intrinsik's Renewable Energy Health Team

- Health scientists dedicated to research and consultation in health aspects of renewable energy

Dr. Christopher Ollson, Ph.D. (co-leader)
Dr. Loren Knopper, Ph.D. (co-leader)
Dr. Melissa Whitfield Aslund, Ph.D.
Ms. Lindsay McCallum, M.Env.Sci. (Ph.D. Cand)
Dr. Mary McDaniel, DO, JD, MPH
Dr. Robert Berger, Ph.D.

Review

Highly accessed    Open Access

**Health effects and wind turbines: A review of the literature**

**Loren D Knopper**[1*] and **Christopher A Ollson**[2]

McCallum *et al. Environmental Health* 2014, **13**:9
http://www.ehjournal.net/content/13/1/9

ENVIRONMENTAL HEALTH

RESEARCH    Open Access

Measuring electromagnetic fields (EMF) around wind turbines in Canada: is there a human health concern?

Lindsay C McCallum[1,2], Melissa L Whitfield Aslund[2], Loren D Knopper[2], Glenn M Ferguson[2] and Christopher A Ollson[2*]

Energy Policy 62 (2013) 44–50

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

ELSEVIER    ENERGY POLICY    CrossMark

Projected contributions of future wind farm development to community noise and annoyance levels in Ontario, Canada

Melissa L. Whitfield Aslund, Christopher A. Ollson, Loren D. Knopper*

Noise & Health

A Bi-monthly Inter-disciplinary International Journal
www.noiseandhealth.org

Letter to Editor: Are the findings of "Effects of industrial wind turbine noise on sleep and health" supported?

Christopher A. Ollson,
Loren D. Knopper, Lindsay C. McCallum,
Melissa L. Whitfield-Aslund

006782

*Noise & Health, March-April 2013, Volume 15:63, 148-52*

# The Issue

- Public generally favours the idea of wind energy.



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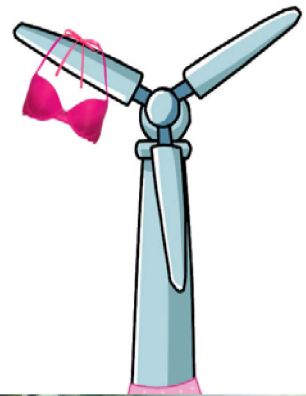
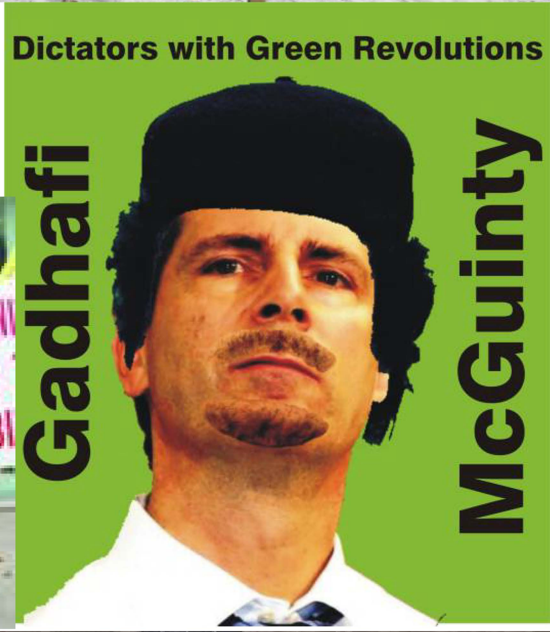
WHEN THE SCIENCE OF WIND ENERGY TURNS INTO THE ART OF PROSTITUTION (EDITORIAL)

Mar 1, 2014



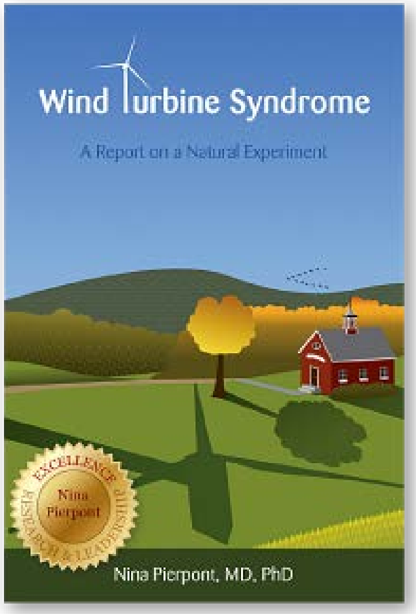





006784

# Wind Turbine Syndrome

- Self-reported symptoms generally included:
  - Annoyance, sleep disturbance, tiredness, headache, tinnitus, irritability, nausea, lack of concentration.
- This collection of effects is commonly called “Wind Turbine Syndrome” (Pierpont, 2009).
- The reason for the self-reported health effects is highly debated.



# Noise and Health

- Environmental noise above certain levels is a recognized factor in a number of human health issues
  - e.g., hearing, sleep, myocardial infarction, annoyance
- Noise from wind turbines can be annoying to some and associated with sleep disturbance
  - especially when found at levels greater than 40 dB(A)
  - WHO (EU) night noise guideline
- Proper siting of wind turbines is key!
  - Even when noise limits are enforced it is possible that a segment of the population may remain annoyed (or report other health impacts)

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# Human Health – The Debate

**Health effects related to wind turbine operation***

– Audible noise
– Low frequency noise
– Infrasound
– Shadow flicker

*often regardless of regulated setbacks

**Health effects related to subjective issues***

– Attitude
– Visual cue
– Stress
– Expectations
– Economics.

*based on proper noise setbacks

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# Weight of Scientific Evidence from ~60 Peer-Reviewed Articles

1. People tend to notice sound from wind turbines almost linearly with increasing sound pressure level

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ORIGINAL ARTICLE

# Wind turbine noise, annoyance and self-reported health and well-being in different living environments

Eja Pedersen, Kerstin Persson Waye

*Occup Environ Med* 2007;**64**:480–486. doi: 10.1136/oem.2006.031039

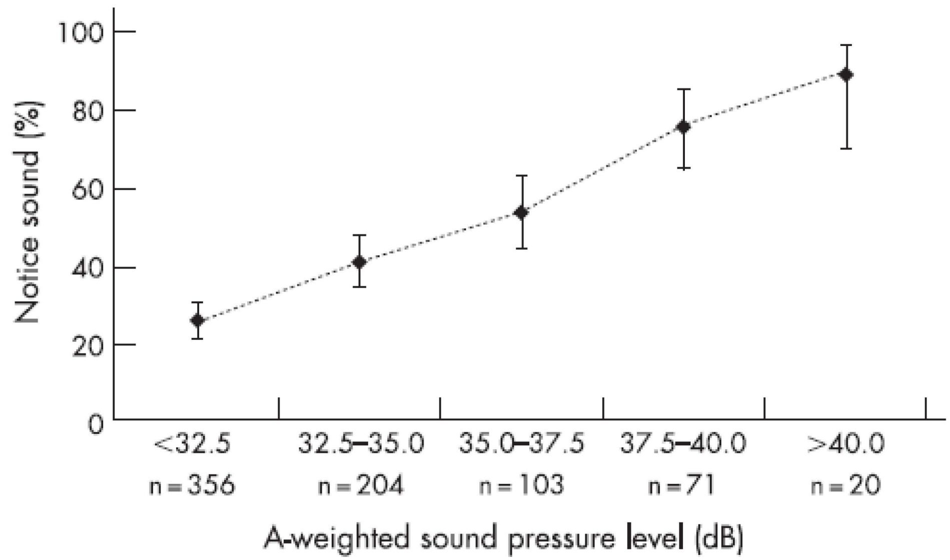


**Figure 1** Proportion of respondents who noticed sound from wind turbines outside their dwelling, in relation to A-weighted sound pressure levels in 2.5-dB intervals. Vertical bars indicate 95% confidence intervals; n, the total number of respondents in each interval.

# Weight of Scientific Evidence

1. People tend to notice sound from wind turbines almost linearly with increasing sound pressure level

2. A proportion of people that notice sound from wind turbines find it annoying

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# A comparison between exposure-response relationships for wind turbine annoyance and annoyance due to other noise sources

Sabine A. Janssen[a] and Henk Vos
*Department of Urban Environment and Safety, Netherlands Organization for Applied Scientific Research, P.O. Box 49, 2600 AA Delft, The Netherlands*

Arno R. Eisses
*Department of Acoustics and Sonar, Netherlands Organization for Applied Scientific Research, P.O. Box 96864, 2509 JG The Hague, The Netherlands*

J. Acoust. Soc. Am. **130** (6), December 2011

Eja Pedersen[b]
*Ecology and Environmental Science, Halmstad University, P.O. Box 823, SE-301 18 Halmstad, Sweden*

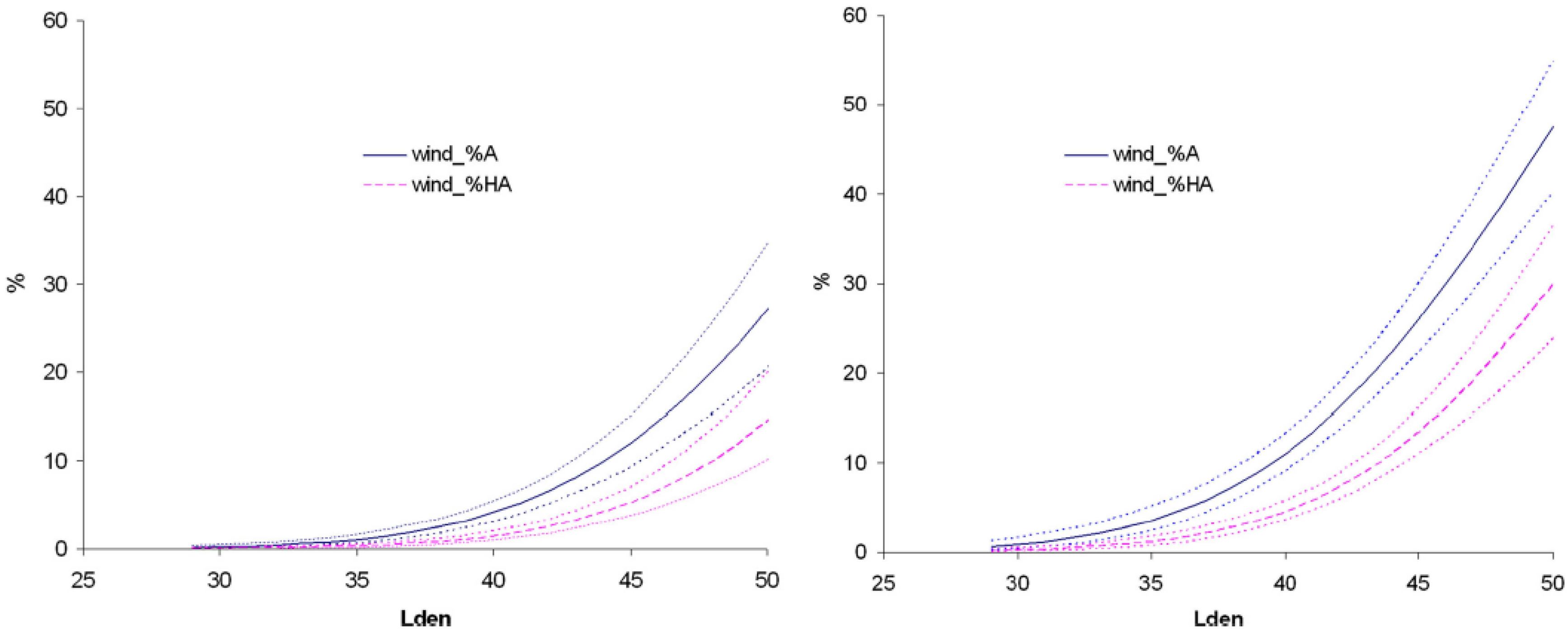


FIG. 1. (Color online) The exposure-response relationships between $L_{den}$ and the percentage of residents annoyed (%A) and highly annoyed (%HA) indoors (left) and outdoors (right).

006791

# Weight of Scientific Evidence

1. People tend to notice sound from wind turbines almost linearly with increasing sound pressure level

2. A proportion of people that notice sound from wind turbines find it annoying

3. Noise-related annoyance from turbines can be within the range of existing levels of community noise related annoyance

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# Impact of Wind Turbine Noise in The Netherlands

Verheijen, E., Jabben, J., Schreurs, E., Smith, K.B
Noise & Health, November-December 2011, Volume 13:55, 459-63

National Institute for Public Health
and the Environment
*Ministry of Health, Welfare and Sport*

- "*The percentage of severely annoyed at 45 dB* [Lden] *is rated at 5.2% for wind turbine noise, which is well below 10% that corresponds to the existing road and railway traffic noise limits".*

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# Weight of Scientific Evidence

1. People tend to notice sound from wind turbines almost linearly with increasing sound pressure level

2. A proportion of people that notice sound from wind turbines find it annoying

3. Noise-related annoyance can be within the range of existing levels of community noise related annoyance

4. People who economically benefit from wind turbines have significantly decreased levels of annoyance compared to individuals that received no economic benefit

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Science of the Total Environment 425 (2012) 42–51

Contents lists available at SciVerse ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

# Impact of wind turbine sound on annoyance, self-reported sleep disturbance and psychological distress

R.H. Bakker [a,*], E. Pedersen [b], G.P. van den Berg [c], R.E. Stewart [d], W. Lok [a,1], J. Bouma [e]

**Table 4**
Response to indoor wind turbine sound among economically benefitting and non-benefitting respondents.

| | Response | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Do not notice | | Notice, not annoyed | | Slightly annoyed | | Rather annoyed | | Very annoyed | | Total | |
| | n | % | n | % | n | % | n | % | n | % | n | % |
| No economical benefit | 394 | 68 | 98 | 17 | 46 | 8 | 21 | 4 | 20 | 4 | 579 | 100 |
| Economical benefit | 53 | 54 | 39 | 39 | 7 | 7 | 0 | 0 | 0 | 0 | 99 | 100 |

**Table 7**
Sound sources of sleep disturbance in rural and urban area types, only respondents who did not benefit economically from wind turbines.

| Sound source of sleep disturbance | Rural | | Urban | | Total | |
|---|---|---|---|---|---|---|
| | n | % | n | % | n | % |
| Not disturbed | 196 | 69.8 | 288 | 64.9 | 484 | 66.8 |
| Disturbed by people/ animals | 33 | 11.7 | 64 | 14.4 | 97 | 13.4 |
| Disturbed by traffic/ mechanical sounds | 35 | 12.5 | 75 | 16.9 | 110 | 15.2 |
| Disturbed by wind turbines | 17 | 6.0 | 17 | 3.8 | 34 | 4.7 |
| Total | 281 | 100 | 444 | 100 | 725 | 100 |

# Weight of Scientific Evidence

1. People tend to notice sound from wind turbines almost linearly with increasing sound pressure level

2. A proportion of people that notice sound from wind turbines find it annoying

3. Noise-related annoyance can be within the range of existing levels of community noise related annoyance

4. People who economically benefit from wind turbines have significantly decreased levels of annoyance compared to individuals that received no economic benefit

5. Annoyance is not only related to wind turbine noise but also to subjective factors like attitude, visual cue, stress and expectations

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# Perception and annoyance due to wind turbine noise—a dose–response relationship

Eja Pedersen[a)] and Kerstin Persson Waye

J. Acoust. Soc. Am. **116** (6), December 2004

Health Psychology


0278-6133/13/$12.00 http://dx.doi.org/10.1037/a0031760

# Can Expectations Produce Symptoms From Infrasound Associated With Wind Turbines?

Fiona Crichton, George Dodd, Gian Schmid, Greg Gamble, and Keith J. Petrie
University of Auckland

Health Psychol. 2013 Nov 25. [Epub ahead of print]

# The Power of Positive and Negative Expectations to Influence Reported Symptoms and Mood During Exposure to Wind Farm Sound.

Crichton F, Dodd G, Schmid G, Gamble G, Cundy T, Petrie KJ.

# The Effects of Vision-Related Aspects on Noise Perception of Wind Turbines in Quiet Areas

Luigi Maffei [1,*], Tina Iachini [2], Massimiliano Masullo [1], Francesco Aletta [1], Francesco Sorrentino [1], Vincenzo Paolo Senese [2] and Francesco Ruotolo [2]

*Int. J. Environ. Res. Public Health* **2013**, *10*

OPEN ACCESS Freely available online

PLOS | ONE

# The Pattern of Complaints about Australian Wind Farms Does Not Match the Establishment and Distribution of Turbines: Support for the Psychogenic, 'Communicated Disease' Hypothesis

**Simon Chapman*, Alexis St. George, Karen Waller, Vince Cakic**
Sydney School of Public Health, University of Sydney, New South Wales, Australia

006797

# MEASUREMENT AND LEVEL OF INFRASOUND FROM WIND FARMS AND OTHER SOURCES

Chris Turnbull, Jason Turner and Daniel Walsh
Acoustics Australia Vol. 40, No. 1, April 2012 - 45

- Infrasound is prevalent in urban and coastal environments at similar (or greater) levels to the level of infrasound measured close to a wind turbine.

Table 2. Measured levels of infrasound

| Noise Source | Measured Level (dB(G)) |
|---|---|
| Clements Gap Wind Farm at 85m | 72 |
| Clements Gap Wind Farm at 185m | 67 |
| Clements Gap Wind Farm at 360m | 61 |
| Cape Bridgewater Wind Farm at 100m | 66 |
| Cape Bridgewater Wind Farm at 200m | 63 |
| Cape Bridgewater Wind Farm ambient | 62 |
| Beach at 25m from high water line | 75 |
| 250m from coastal cliff face | 69 |
| 8km inland from coast | 57 |
| Gas fired power station at 350m | 74 |
| Adelaide CBD at least 70m from any major road | 76 |

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# Weight of Scientific Evidence

- Based on the findings and scientific merit of the available studies, the weight of evidence suggests that when sited properly, wind turbines are not related to adverse health effects

- Government findings
  - National Health and Medical Research Council in Australia, 2010
  - Chief Medical Officer of Health (ON), May 2010
  - MassDEP and MDPH, 2012
  - Oregon Health Authority, 2013
  - National Health and Medical Research Council in Australia, 2014

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# Intrinsik's Health Based Siting Recommendations

1. Setbacks should be sound-based rather than distance-based alone.

2. Preference should be given to sound emissions of ≤40 dBA (outside, not including ambient) for non-participating individuals.

3. Post construction monitoring should be common place to ensure actual sound levels are within required noise limits.

4. If sound emissions from wind projects in the 40-45 dB(A) range for non-participating individuals, we suggest community consultation and community support.

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# Intrinsik's Health Based Siting Recommendations

5. Setbacks of >45 dB(A) (wind turbine noise only; not including ambient noise) for non-participating individuals directly outside a dwelling are not supported due to possible direct effects from audibility and possible levels of annoyance above background.

6. When ambient noise is taken into account, wind turbine noise can be >45 dB(A), but a combined wind turbine-ambient noise should not exceed >55 dB(A) for non-participating and participating individuals.

intrinsik
SCIENCE INTEGRITY KNOWLEDGE

# Red Lily Legal Challenge

**QUEEN'S BENCH FOR SASKATCHEWAN**

Citation: **2010 SKQB 374**

| | |
|---|---|
| Date: | **2010 10 07** |
| Docket: | Q.B.G. No. 1251 of 2010 |
| Judicial Centre: | Saskatoon |



BETWEEN:

DAVID McKINNON

PLAINTIFF

- and -

THE RURAL MUNICIPALITY OF MARTIN NO. 122, and THE RURAL MUNICIPALITY OF MOOSOMIN NO. 121, RED LILY WIND ENERGY CORP. and 7314507 CANADA INC., operating as a general partnership known as RED LILY WIND ENERGY PARTNERSHIP

DEFENDANTS

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SCIENCE INTEGRITY KNOWLEDGE

# Alberta AUC Rule 012 Upheld

BluEarth™
RENEWABLES INC.

## Bull Creek wind project approved by Alberta Utilities Commision

Story | Comments | Image (1) — Share | Print | Font Size:

Tweet 1 | Like 0

Posted: Friday, February 28, 2014 12:06 pm

Kelly Clemmer, Editor-in-Chief | 0 comments

The Alberta Utilities Commission have approved the application to build the BluEarth Renewable's Bull Creek Wind Project, February 20, 2014, at the south border of the MD of Wainwright and northern border of the MD of Provost.

"All of the councillors were pleased with the end result," said Jim Klasson, the MD of Wainwright's development officer. "Council and admin supported the project.

"It can't be overlooked that the rest of the province knows that we're open for business," said Klasson.

The Bull Creek wind energy project was applied for in June, 2012, and after a number of steps in the process, the Killarney Lake Group (KLG) opposed the project. AUC held public hearings on October 28, 2013 to November 1, 2013 in Provost. The hearing resumed in Calgary from November 18 to 22. It was from that hearing that AUC made its decision, that the Bull Creek project was "in the public's interest."

AUC
Alberta Utilities Commission

**1646658 Alberta Ltd.**

**Bull Creek Wind Project**

**February 20, 2014**

# Thank you

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**PREPARED BY & RETURN TO**

Orin Shakerdge, Esq.
FPL Energy, LLC
700 Universe Blvd.
Juno Beach, FL 33408
Telephone: (561) 694-4678

Doc# 2007-6498 5pp
State of South Dakota } SS. Fees 18-
County of Codington
OFFICE OF REGISTER OF DEEDS
Filed this 27th day of Nov 2007 at 12:35 o'clock P m
Book 45 Page 865
Ann Seitel
REGISTER OF DEEDS/DEPUTY
(This space reserved for recording information)

# MEMORANDUM OF OPTION FOR EASEMENT AGREEMENT

**THIS MEMORANDUM OF OPTION FOR EASEMENT AGREEMENT** ("**Memorandum**") is made as of July 2, 2007 (the "**Effective Date**") by and between **Dennis D. Thyen and Dawn M. Thyen, Husband and Wife,** ("**Owner**") whose address for purposes of notices is: **46310 164th St., Watertown, SD 57201** ("**Owners**"), and Boulevard Associates, LLC, a Delaware limited liability company, a subsidiary of FPL Energy LLC, a Delaware limited liability company, whose address for purposes of notices is: 700 Universe Blvd., Attn: Business Manager, Juno Beach, FL 33408 ("**FPLE**"). Each of Owner and FPLE shall hereinafter be referred to individually as a "**Party**" and collectively as the "**Parties.**"

## RECITALS

WHEREAS, Owner and FPLE are the parties in and to an Option for Easement Agreement dated July 2, 2007 ("**Agreement**"), by which Owner granted to FPLE an exclusive option for easements over and across certain real property located in the County of **Codington**, State of South Dakota, described on the attached Exhibit A as the "**Property**" and as owned by Owner.

WHEREAS, Owner and FPLE desire to execute, deliver and record this Memorandum for the purpose of putting all persons on notice of FPLE's right, title and interest in the Property.

NOW, THEREFORE, for good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged, Owner and FPLE do hereby state, declare and establish as follows:

## AGREEMENT

1. **Grant of Option**. Commencing on the Effective Date, Owner hereby grants to FPLE an exclusive option to enter into an agreement creating certain easement rights and obligations affecting the Property, for wind energy development purposes ("**Option**").

2. **Term & Termination**. The term of the Option shall commence on the Effective Date and terminate on the date that is three (3) years after the Effective Date ("**Initial Option Period**"). The Initial Option Period may be extended for a three (3) year period on the same



EXHIBIT I 11

006805

2. **Term & Termination**. The term of the Option shall commence on the Effective Date and terminate on the date that is three (3) years after the Effective Date (**"Initial Option Period"**). The Initial Option Period may be extended for a three (3) year period on the same terms and conditions set forth in the Agreement (**"Renewal Option Period"**). The Initial Option Period and, if applicable, the Renewal Option Period shall be referred to hereinafter collectively as the **"Option Period"**. FPLE may terminate the Option at any time during the Option Period upon written notice to Owner.

3. **Exercise of Option**. FPLE may exercise the Option at any time during the Option Period upon after providing written notice to Owner. If FPLE exercises the Option in accordance with the terms contained herein, the Parties agree to negotiate in good faith and with due diligence to execute an agreement creating the easement rights and obligations contemplated hereby, within sixty (60) days after the exercise of the Option.

4. **Exclusivity**. During the Option Period, Owner will not sell, contract to sell, assign, lease, negotiate with another wind farm developer, or otherwise transfer or encumber the Property or any part thereof or interest therein, unless it is transferred or encumbered subject to FPLE's rights under the Agreement. In no event will Owner, during the Option Period, grant a license, easement, option, leasehold, or other rights to the Property, or any part thereof, to any other utility or entity seeking, directly or indirectly, to develop the Property, or any part thereof, for wind energy conversion, or to negotiate with any other party with respect to such rights, nor permit any third party to undertake activities on the Property to evaluate the wind resources of the Property, or any part thereof.

5. **Interpretation of this Memorandum**. The purpose of this Memorandum and its recordation in **Codington** County, South Dakota is to place all persons on notice of the existence of the Agreement. It is understood and agreed by the Parties that this Memorandum shall not modify or amend the Agreement in any respect. All of the terms, covenants and conditions contained in the Agreement and this Memorandum shall be deemed covenants running with the land for all purposes.

6. **Counterparts**. This Memorandum may be executed in two or more counterparts, each of which will be deemed an original, but all of which together shall constitute one and the same instrument.

IN WITNESS WHEREOF, the parties have executed this Memorandum as of the Effective Date.

**Owner:**

Signature: ______________________
Dennis D. Thyen

Signature: ______________________
Dawn M. Thyen

**BA:**
Boulevard Associates, LLC
A Delaware limited liability company

By: ______________________
Dean Gosselin, Vice President

## ACKNOWLEDGEMENT

To be filled out by Notary Public for Land Owner:

State of South Dakota )
)ss:
County of Codington )

On this 31st day of May, 2007, before me, the undersigned notary public, personally appeared Dennis D and Dawn M. Thyen, personally known to me to be the person who subscribed to the foregoing instrument or provided a driver's license as identification.

IN WITNESS WHEREOF, I hereunto set my hand and official seal.

*(notary seal)*

TODD C. ANDERSON
SEAL NOTARY PUBLIC SOUTH DAKOTA SEAL

Todd C. Anderson
Notary Public, State of South Dakota

My commission expires: 5/24/2013

State of Florida )
)ss:
County of Palm Beach)

On this 2 day of July, 2007, before me, the undersigned notary public, personally appeared **Dean R. Gosselin,** personally known to me to be the person who subscribed to the foregoing instrument and acknowledged that he executed the same on behalf of said limited liability company and that he was duly authorized so to do.

IN WITNESS WHEREOF, I hereunto set my hand and official seal.

*(notary seal)*

KIM L OTTO
MY COMMISSION # DD 281012
EXPIRES: March 28, 2008
Bonded Thru Notary Public Underwriters

Notary Public, State of Florida
My commission expires: 3.28.08

## EXHIBIT A

## Real Property Description

The West 830 feet of the Southwest Quarter (SW1/4) of Section 22, Township 118 North, Range 51 West of the 5th P.M., except the Railroad right-of-way contained therein; except that portion conveyed to Codington County for roadway purposes and described in Quit Claim Deed filed in Book 185 of Deeds on page 67. **Codington County, South Dakota**

# Boulevard Associates, LLC

*700 Universe Blvd.*
*Juno Beach, FL 33408-2683*

8/31/2012

*DENNIS D AND DAWN M THYEN*
*46310 164TH STREET*
*WATERTOWN, SD 57201*

Re: Wind Farm Agreement

*Dear DENNIS D AND DAWN M THYEN,*

As you are aware, the wind farm agreement we have on your property renews annually. After a thorough review of the opportunities for wind energy in your area, we have decided to not renew your agreement at this time.

I want to personally thank you for your participation and cooperation as we gathered data for a potential wind project in your community. The decision to discontinue your agreement was based on a list of criteria, including market opportunities, wind resource and environmental that leads us to the decision to terminate your wind farm agreement with Boulevard Associates, LLC. Based on this determination, we will also be discontinuing any further payments.

We will continue to monitor this region. If market conditions change and we believe this project is viable in the future, we will contact you. Should you have any questions please feel free to contact me at (561) 691-7240.

Sincerely,

Scott Scovill
Director Development

cc: Mikel Greene

EXHIBIT
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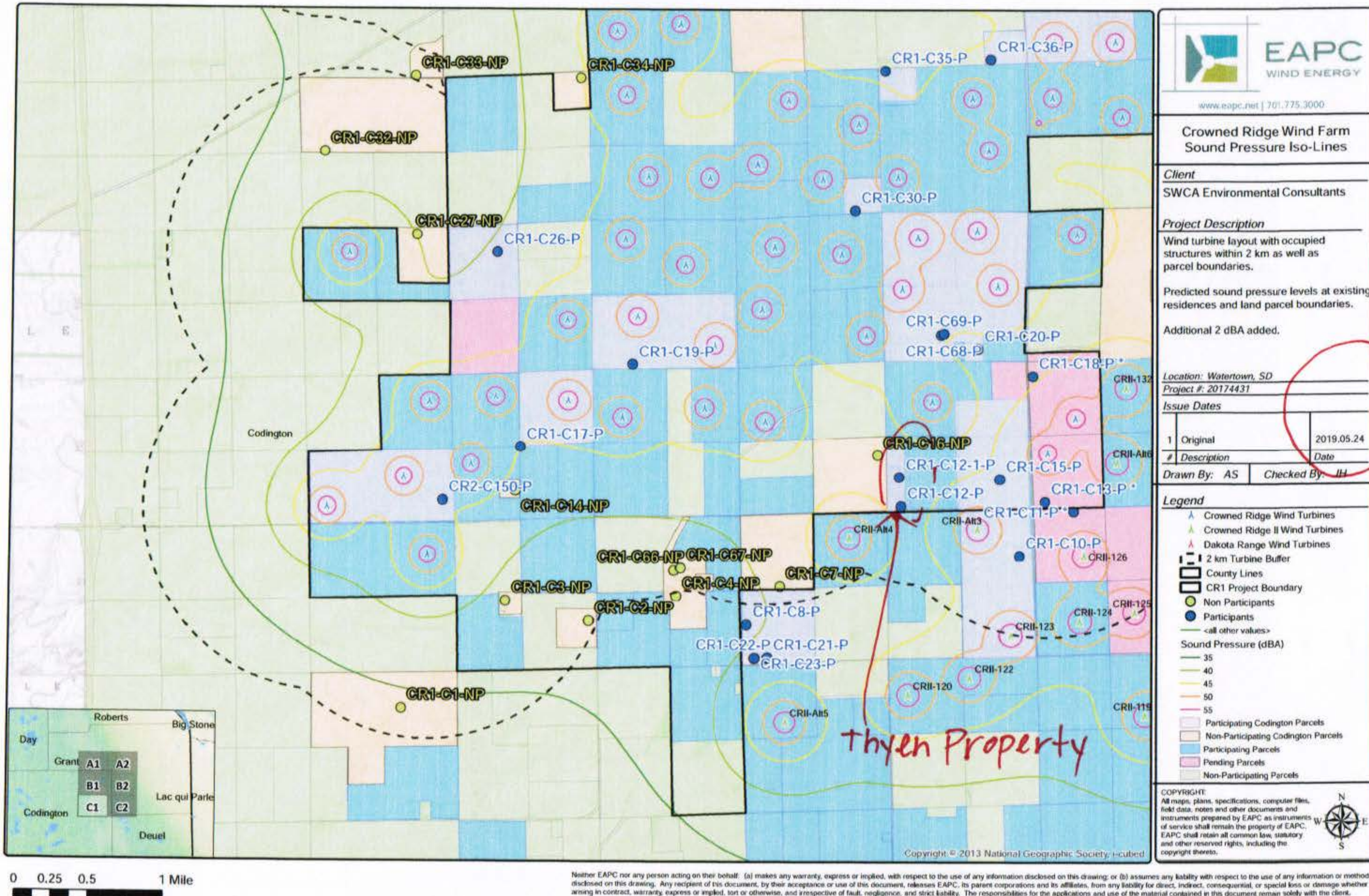


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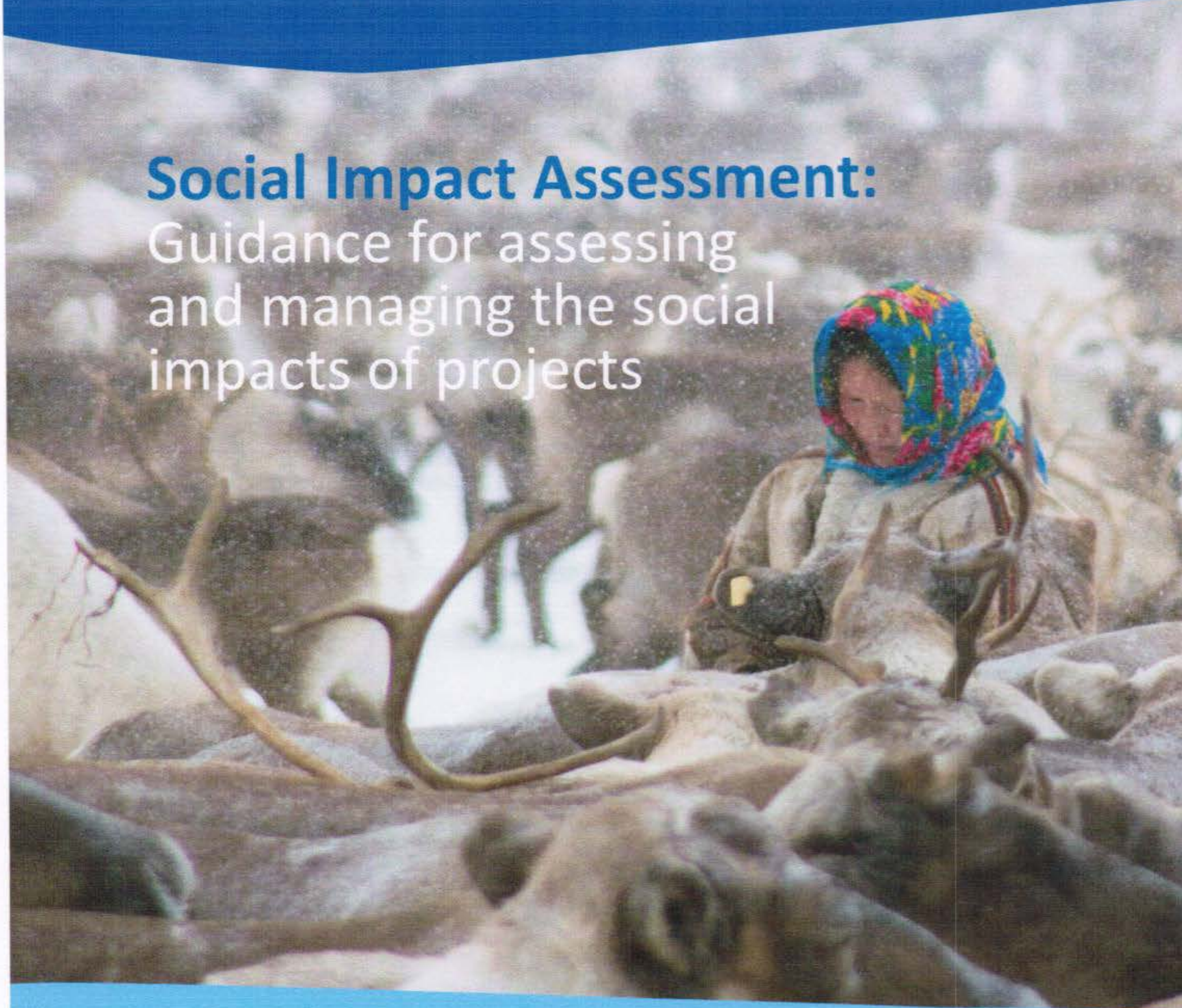
EXHIBIT
I13

IAIA International Association for Impact Assessment

# Social Impact Assessment:
## Guidance for assessing and managing the social impacts of projects




**Principal author:**
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Ana Maria Esteves, *Community Insights Group*
Ilse Aucamp, *Equispectives Research & Consulting Services*
Daniel M. Franks, *University of Queensland*


April 2015

EXHIBIT
I14

## Purpose and intended readership

The purpose of this Guidance Note is to provide advice to various stakeholders about what is expected in good practice social impact assessment (SIA) and social impact management processes, especially in relation to project development. Project development refers to dams, mines, oil and gas drilling, factories, ports, airports, pipelines, electricity transmission corridors, roads, railway lines and other infrastructure including large-scale agriculture, forestry and aquaculture projects. This Guidance Note builds on IAIA's (2003) *International Principles for Social Impact Assessment.* While the International Principles outline the overarching understandings of the SIA field, including the expected values of the profession, this document seeks to provide advice on good practice in the undertaking and appraisal of SIAs and the adaptive management of projects to address the social issues. As a statement of good and sometimes leading practice, not all the information in this document will necessarily be applicable in every situation – people utilising this information will need to establish for themselves what is appropriate in each particular context.

The intended users of this document include:

- SIA Practitioners/Consultants who want to know how their practice compares with international best practice;
- Project Developers/Proponents (private sector or government) to assist them in evaluating SIA consultants and in knowing what to expect from consultants;
- Regulatory agencies in terms of judging the quality and acceptability of SIA reports and in determining what procedures and expectations will be;
- Social specialists in the Multilateral Development Banks (MDBs), such as the World Bank, the International Finance Corporation (IFC), the Asian Development Bank (ADB), the African Development Bank (AfDB), European Bank of Reconstruction and Development (EBRD), the European Investment Bank (EIB), and the Inter-American Development Bank (IDB);
- Social staff in other financial institutions, especially Equator Principles banks;
- Development cooperation agencies;
- Government planning agencies;
- Communities and local peoples;
- Civil society organizations;
- People responsible for SIA regulatory frameworks.

## Acknowledgements

Hundreds of people made contributions to the discussions at conferences of the International Association for Impact Assessment and elsewhere that have been incorporated into this document. Some people deserve special mention because of their particularly significant contribution, including: San-Marie Aucamp, James Baines, Hilda Bezuidenhout, Eelco de Groot, Damien Eagling, Gabriela Factor, Cornelia Flora, Nora Götzmann, Philippe Hanna, Angelo Imperiale, Deanna Kemp, Ivo Lourenço, Lucy McCombes, Behrooz Morvaridi, Ciaran O'Faircheallaigh, Marielle Rowan, Helen Russell, Rauno Sairinen, Arn Sauer, Frank Seier, Eddie Smyth, Mike Steyn, Nick Taylor, Lidewij van der Ploeg, Francesca Viliani, and Jorge Villegas.

## Disclaimer

This document provides general guidance about what the International Association for Impact Assessment (IAIA) considers to be current good practice in social impact assessment at the time of publication. It is provided only as a general public service to the professional community and does not constitute the provision of legal or technical advice. Since jurisdictions vary greatly in their laws and requirements, practitioners will always need to confirm the expectations in any context in which they work. Reference to any company or corporation in this document does not necessarily constitute endorsement or support. IAIA accepts no liability for errors or omissions, or for any consequences that may come from following this advice.

## About the cover photo

Reindeer herding brigade number 4, Yar Sale municipal farm, South Yamal Peninsula, April 2012, Photo taken by Florian Stammler, Arctic Centre, University of Lapland. Used with permission

Several times a week, before the journey to the next campsite, the families in each brigade of nomadic herders round up their reindeer and choose the ones they will use to pull the sledges with their household items. It is each sledge driver's responsibility to choose the animals they want.

# About the authors

**Prof Frank Vanclay**, who is Australian by birth, is now professor of cultural geography in the Faculty of Spatial Sciences at the University of Groningen, the Netherlands. Growing up in north-eastern Australia in a region undergoing rapid development led him to have a life-long interest in social impact assessment and the governance of development. Although a career academic, his strong interest in applied social research and a commitment to the social relevance of academic research has meant he has been frequently engaged to be advisor on social issues generally and especially on social impact assessment for a wide range of organisations, including the World Commission of Dams, the World Bank, government agencies in many countries, and various international NGOs and industry organisations. He has been a visiting professor at the University of Eastern Finland and the University of Sao Paulo. He has been associated with IAIA for over 25 years, holding many leadership positions, for example, he is the current Chair of the Editorial Board of IAIA's journal, *Impact Assessment & Project Appraisal*. He is the author of many of the key documents in the field of social impact assessment, and was the 2014 recipient of IAIA's individual award acknowledging his personal contribution to advancing the theory and practice of the discipline of social impact assessment. E-mail: **frank.vanclay@rug.nl**

**Dr Ana Maria Esteves**, who is Mozambican by birth but now resident in the Netherlands, has had a long term interest in the topic of how the extractives sector can contribute to social development. She established the social performance consulting firm, Community Insights Group, in 2002. Ana Maria and CIG have provided support in the areas of social performance and local content to many global resources companies such as Shell, BG, Tullow Oil, Anglo American, Rio Tinto and BHP Billiton, in all regions of the world. Although primarily a practitioner, she has published widely on social impact assessment and local content issues, and is a visiting Professor in the Department of Civil and Environmental Engineering at the University of Strathclyde in Glasgow, Scotland. She will be President of IAIA in 2016-2017, having previously served in many leadership roles in IAIA. She founded and manages SIAhub (**http://www.socialimpactassessment.com**), an online platform for SIA practitioners.
E-mail:**amesteves@communityinsights.eu**

**Dr Ilse Aucamp** is South African by birth. Working as an SIA practitioner, she is a qualified social worker with a masters degree in environmental management, and has just completed her DPhil degree on how SIA can be used as a tool for social development. She is a director of Equispectives Research and Consulting Services, a firm specialising in social research and the social aspects of environmental management. Ilse has mainly worked in Africa and has conducted more than 100 SIA studies during her career, including for many mining and large infrastructure projects. She has also been involved in the long term monitoring of social aspects during project implementation. She teaches SIA at a post graduate level at a number of South African universities. Her involvement with IAIA includes being a member of the National Executive Committee of IAIA South Africa and being a past-chair of the SIA section of IAIA international. Ilse is on the advisory panel of the Centre for Environmental Rights, a NGO in South Africa specialising in social and environmental justice. She finds working with grassroots communities the most rewarding aspect of SIA.
E-mail: **ilse@equispectives.co.za**

**Dr Daniel Franks**, who is Australian by birth, is Deputy Director at the Centre for Social Responsibility in Mining at The University of Queensland's Sustainable Minerals Institute. With a background in geology, policy and social sciences, his research and practice is focussed on the sustainability challenges of mining and energy development. He has served as Co-Chair of the SIA section of IAIA since 2011 and is a member of the Good Governance of Extractive and Land Resources Thematic Group of the United Nations Sustainable Development Solutions Network. He has published widely in the academic literature and has undertaken research for organisations including: UNDP, The World Bank, Oxfam, the Ford Foundation, Greenpeace, the Australian Agency for International Development, the International Council on Mining and Metals and most of the major mining companies. He has been a visiting lecturer at the Universidad Católica del Norte, Chile; Columbia University, New York; the University of Eastern Finland; and the University of Western Australia. E-mail: **d.franks@smi.uq.edu.au**



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# Key points of this guidance document

Social Impact Assessment (SIA) is now conceived as being the process of identifying and managing the social issues of project development, and includes the effective engagement of affected communities in participatory processes of identification, assessment and management of social impacts. Although SIA is still used as an impact prediction mechanism and decision-making tool in regulatory processes to consider the social impacts in advance of a permitting or licensing decision, equally important is the role of SIA in contributing to the ongoing management of social issues throughout the whole project development cycle, from conception to post-closure. Like all other fields of practice (discourses), SIA is a community of practice with its own paradigm of theories, methods, case histories, expected understandings and values. What is meant and implied by 'social impact assessment' is the understanding of it within the SIA paradigm rather than any dictionary interpretation of the words, social, impact, or assessment. This paradigm is embodied and articulated in the *International Principles for Social Impact Assessment* and in this guidance document.

SIA arose in the 1970s alongside environmental impact assessment (EIA) and originally attempted to emulate EIA as much as possible. Often SIA was done as part of EIA, usually badly. Over time, however, the practice of SIA has diverged from EIA because of the growing realisation that social issues fundamentally differ from biophysical issues; that the primary task of SIA should be to improve the management of social issues (rather than to only influence go/no go decisions); and that the effectiveness of SIA in terms of achieving better outcomes for affected communities will be maximised by being relevant to the proponents (commercial and public sector developers) who initiate and implement projects. Because of the interconnectedness of environmental, social and health issues, it is worthwhile to conduct integrated assessments, and ESHIA (environmental, social and health impact assessment) has become standard practice in the private sector. However, social impacts start long before project approval is required – they start with rumours of a possible project. Managing the social issues (and thus SIA), therefore, needs to start as soon as possible after projects are conceived.

A key difference between SIA and EIA is the increasing focus in SIA on enhancing the benefits of projects to impacted communities. Although the need to ensure that the negative impacts are identified and effectively mitigated remains, also of value is revising projects and ancillary activities to ensure greater benefits to communities. This is necessary for the project to earn its 'social licence to operate'; and also because attempting to minimise harm (the traditional approach in SIA) does not ensure that the project will be considered acceptable by local stakeholders, or that a project does not actually cause significant harm. Enhancing benefits covers a range of issues, including: modifying project infrastructure to ensure it can also service local community needs; providing social investment funding to support local social sustainable development and community visioning processes to establish strategic community development plans; a genuine commitment to maximising opportunities for local content (i.e. jobs for local people and local procurement) by removing barriers to entry to make it possible for local enterprises to supply goods and services; and by providing training and support to local people. Where people are resettled to enable a project to proceed, it is essential to ensure that their post-resettlement livelihoods are restored and enhanced.

Important to earning a social licence to operate is to treat communities with respect. Meaningful, transparent and ongoing community engagement practices from the earliest stages of any intervention are essential to build trust and respect. The key values and principles of SIA are specified in the *International Principles for Social Impact Assessment*. The established principles of SIA include: the objective of SIA and the project should be to contribute to the empowerment of vulnerable groups in the community; a gender lens should be applied in all assessments; and that respect for human rights should underpin all actions. The rise of the Business and Human Rights discourse, especially with the adoption of the *United Nations Guiding Principles on Business and Human Rights*, means that respect for human rights is now a fundamental responsibility of private sector developments. With many social and environmental impacts interpretable in terms of human rights, SIA will have increasing traction. Impacted peoples are rights-holders with legal entitlements, and SIA can demonstrate its value to companies as a way of reducing their risk exposure and assist them in being compliant with international standards and/or good practice as they evolve over time. Ideally, SIA and comprehensive ESHIA should address all significant human rights issues associated with a project.

## Some key background concepts relevant to SIA

Although an extensive glossary is provided at the end of this document, here some key concepts that are central to understanding the issues involved in the management of social impacts are introduced and described.

**Social Licence to Operate** refers to the level of acceptance or approval of the activities of an organization by its stakeholders, especially local impacted communities. Leading corporations now realize that they need to meet more than just the regulatory requirements, they also need to consider, if not meet, the expectations of a wide range of stakeholders, including international NGOs and local communities. If they don't, they risk not only reputational harm and the reduced opportunities that might bring, they also risk being subject to strikes, protests, blockades, sabotage, legal action and the financial consequences of those actions. In some countries, 'social licence' has become an established element of the language of business, actively influencing, if not driving, the business strategy of many companies, and is part of the governance landscape. **For more information**, refer to: Boutilier, R.G. 2014 Frequently asked questions about the social licence to operate. *Impact Assessment & Project Appraisal* 32(4), 263-272. **http://dx.doi.org/10.1080/14615517.2014.941141**

**Free, Prior and Informed Consent (FPIC)** is a procedural mechanism developed to assist in ensuring the right of Indigenous peoples to self-determination. It is a concept that gained status by its inclusion in the 2007 *United Nations Declaration on the Rights of Indigenous Peoples* and the 1989 International Labour Organization's Convention 169. Its legal status varies depending on whether a country has signed one or the other of these instruments and has effectively incorporated it into domestic law. 'Free' means that there must be no coercion, harassment, intimidation or manipulation by companies or governments in order to obtain stakeholder consent, and should a community say 'no' there must be no retaliation. 'Prior' means that consent should be sought and received before any activity on community land is commenced and that sufficient time is provided for adequate consideration by any affected communities. 'Informed' means that there is full disclosure by project developers of their plans in a language and format that is acceptable to the affected communities, and that each community has enough information and capacity to have a reasonable understanding of what those plans will likely mean for them, including of the social impacts they will experience. Although 'consent' would normally imply that communities should have a real choice, that they can say yes if there is a good flow of benefits and development opportunities to them, or they can say no if they are not satisfied with the deal, and that there is a workable mechanism for determining whether there is broad-based support in the community as a whole, in reality the implementation of FPIC often remains flawed. FPIC, to varying extents, has been adopted as a requirement by the IFC and many other international organisations. There is an increasing discussion about whether the spirit of FPIC should be used to demonstrate respect for all communities and to earn a social licence to operate. **For more information**, refer to: Buxton, A. & Wilson, E. 2013 *FPIC and the Extractive Industries: A Guide to applying the Spirit of Free, Prior and Informed Consent in Industrial Projects*, London: IIED. **http://pubs.iied.org/pdfs/16530IIED.pdf**

**A human rights-based approach** refers to a conceptual and procedural framework directed towards ensuring the promotion and protection of human rights in policies, programs, plans and projects. It is the basis of all human rights relevant instruments and actions and has been applied in a wide range of contexts (notably in health and development cooperation). It seeks to: (1) position human rights and its principles as the core element of actions; (2) demand accountability and transparency by duty-bearers towards rights-holders; (3) foster empowerment and capacity building of rights-holders to, inter alia, hold duty-bearers to account; (4) ensure that the meaningful participation of rights-holders in development processes and planned interventions is recognised as an intrinsic right, not simply as best practice; and (5) ensure the non-discriminatory engagement of rights-holders and the prioritization of especially-vulnerable or marginalized individuals or groups (e.g. women, elderly, children and youth, minorities and Indigenous peoples).
**For more information**, refer to: **http://hrbaportal.org/**

**Human rights due diligence** refers to the expectation in the *United Nations Guiding Principles on Business and Human Rights* that companies must carry out a due diligence process in order to ensure that a proposed business action, transaction or acquisition has no hidden human rights risks (in other words, risks to people and communities, not only risks to the company). Since many social impacts are also human rights impacts, affected stakeholders are rights-holders with legal rights. This increases the significance of social impacts and the importance of social impact assessment. Social impacts are therefore serious matters that companies must address. **For more information**, refer to: ICMM 2012 *Integrating Human Rights Due Diligence into Corporate Risk Management Processes.* **http://www.icmm.com/document/3308**



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**Non-technical risks** relate to the managerial, legal, social and political issues faced by a project, in contrast to the technical risks (i.e. the physical, structural, engineering and environmental risks). The technical and technocratic focus of many project staff (and their asocietal mentality) means that the technical risks are usually fully considered whereas the non-technical risks are under-considered or ignored altogether. Nevertheless, because of the protest actions local communities can take, non-technical risks are potentially serious financial risks to a project and therefore should be fully considered and addressed. **For more information**, refer to: Davis, R. & Franks, D. 2014 *Costs of Company-Community Conflict in the Extractive Sector*. **http://www.hks.harvard.edu/m-rcbg/CSRI/research/Costs%20of%20Conflict_Davis%20%20Franks.pdf**

**Social risk** has different meanings in different discourses. In the SIA/corporate project discourse, 'social risk' is a largely similar concept to 'non-technical risk' and is the preferred term. The World Bank defines social risk as "the possibility that the intervention would create, reinforce or deepen inequity and/or social conflict, or that the attitudes and actions of key stakeholders may subvert the achievement of the development objective, or that the development objective, or means to achieve it, lack ownership among key stakeholders". For the Bank, social risk is considered to be both risk (threats) to the success of the project, but also risk (social issues) created by the project, which in turn become threats to the project. In a corporate setting, social risk can be regarded as the business risks (e.g. extra costs) to the company that arise from any social impacts or social issues created by the project, such as through unforeseen costs of mitigation, future litigation and/or compensation payouts, worker strikes, retaliatory acts of sabotage, and reputational harm. **For more information**, refer to: Kytle, B. & Ruggie, J. 2005 *Corporate Social Responsibility as Risk Management: A Model for Multinationals*. **http://www.ksg.harvard.edu/m-rcbg/CSRI/publications/workingpaper_10_kytle_ruggie.pdf**

**Impacts & Benefits Agreements** (or Community Development Agreements) are negotiated agreements between project developers and affected peoples. Although sometimes including governments, these agreements typically are between a project developer and the impacted stakeholders, although the impetus and content may be influenced by government policy. Agreements normally include statements about the likely residual impacts, provisions about how these impacts are to be addressed, the benefits that have been promised, and the governance processes that will be used to manage the relationship between the parties. **For more information**, refer to: Gibson, G. & O'Faircheallaigh, C. 2010 *IBA Community Toolkit: Negotiation and Implementation of Impact and Benefit Agreements*. Toronto: Walter & Duncan Gordon Foundation. **http://www.ibacommunitytoolkit.ca**

**Sustainable Livelihoods** refers to a way of thinking about communities and people in terms of their capabilities, and the livelihood resources (assets, capitals) and the livelihood strategies (activities) they undertake to make their living and conduct their way of life. A livelihood refers to the way of life of a person or household and how they make a living, in particular, how they secure the basic necessities of life, e.g. their food, water, shelter and clothing, and live in the community. Livelihoods are interdependent on each other and on the biophysical environment. A livelihood is sustainable when it can cope with and recover from stresses and shocks (i.e. is resilient) and maintain or enhance its capabilities and assets both now and into the future while not undermining the natural resource base. People need a sustainable livelihood in order to survive, and therefore all interventions need to consider the impacts on people's livelihoods. **For more information**, refer to: Scoones, I. 1998 *Sustainable Rural Livelihoods: A Framework for Analysis*, IDS Working Paper 72. **http://mobile.opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/3390/Wp72.pdf**

**Shared value** is a way of thinking about the role of a company that recognizes that societal needs, not just conventional economic needs, define markets, and that the purpose of the corporation must be redefined as creating shared value, rather than just profit for its shareholders, so society benefits as well as the company. This view also acknowledges that social harms frequently create costs for firms in the form of social risks and therefore need to be carefully managed. **For more information**, refer to: Porter, M. & Kramer, M. 2011 Creating shared value. *Harvard Business Review* 89(1-2), 62-77. **http://www.fsg.org/Portals/0/Uploads/Documents/PDF/Creating_Shared_Value.pdf**; Hidalgo, C. et al. 2014 *Extracting with Purpose*. FSG. **http://www.fsg.org/tabid/191/ArticleId/1184/Default.aspx?srpush=true**

The **Equator Principles** (EP) is a corporate social responsibility and sustainability framework for the global finance industry. More specifically, it is a risk management framework adopted by financial institutions (i.e. banks) for determining, assessing and managing environmental and social risk in projects anywhere in the world and for all industry sectors. It is primarily intended to provide a minimum standard for due diligence to support responsible risk decision-making. Banks that adopt the EP commit to implementing the principles in their internal environmental and social policies, procedures, and standards for financing projects and agree to "not provide Project Finance or Project-Related Corporate Loans to projects where the client will not, or is unable to, comply with the EP". The banks that subscribe to the EP provide a substantial majority of the international project finance in developing countries. Essentially the EP are a set of high level principles; for operational guidelines the EP requires compliance with the **IFC Performance Standards**. **For more information**, refer to: **http://www.equator-principles.com** and **http://www.ifc.org/performancestandards**

# Contents

## Social Impact Assessment is a process of management not a product

The *International Principles for Social Impact Assessment* defines SIA as being "the processes of analysing, monitoring and managing the intended and unintended social consequences, both positive and negative, of planned interventions (policies, programs, plans, projects) and any social change processes invoked by those interventions". Although SIA can and has been applied in many different settings, this guidance document addresses the application of SIA at the project level, e.g. the planned construction of new infrastructure such as airports, bridges, bypasses, dams, highways, mines, pipelines, ports, transmission corridors, windfarms, as well as commercial agriculture and agroforestry developments and the creation of nature conservation areas. The planning and construction of these projects can cause many social impacts. From early stages, there typically is speculation about the project that can affect property prices, and can lead either to an exodus of people, or conversely to the influx of people (known as the 'honeypot effect').

Projects can create opportunities and benefits for people, but at the same time they can also create harmful effects. Typically, projects are never uniformly good or bad, there is a differential distribution of costs and benefits within nearby communities. It is too simplistic to talk in terms of winners and losers, because people can be benefitted and harmed at the same time. Good management is needed to ensure that the benefits of projects are maximised and the negative impacts are avoided or minimised on an ongoing basis during the life of the project. SIA is a process that can greatly assist in ensuring the achievement of benefits and the avoidance of harm.

Because SIA involves the processes of managing the social impacts of development and contributes to shared value by improving outcomes for local communities as well as for the developer (corporate or government), it should be undertaken by the project whether it is legally required or not. The amount of effort invested in the SIA to adequately identify and manage social impacts should be commensurate with the likely project impacts and risks. Early scoping activities should help the practitioner identify the relative scale of effort likely to be required.

Rather than the conventional statement of social impacts somewhat akin to an Environmental Impact Statement, a more appropriate document to be produced is a Social Impact Management Plan (SIMP) and related management documents, e.g. Community Health & Safety Plan, Resettlement Action Plan, Stakeholder Engagement Plan, Local Procurement Plan, which collectively provide an integrated set of actions and procedures to manage the social issues created by the project. A SIMP outlines the strategies to be undertaken during each of the phases of a project (including post-closure) to monitor, report, evaluate, review and proactively respond to change. Adaptive management is an important part of managing social impacts. SIMPs are increasingly being required by governments and investors in projects. They are usually developed as an outcome of the preparation of impact statements for project approvals and then periodically updated. Ideally, SIMPs should correspond with and/or feed into the company's internal management systems; alternatively, companies could implement a social impact management system as part of their overall planning process.

**For more information** on Social Impact Assessment as a process of management, refer to:


Esteves, A.M., Franks, D. & Vanclay, F. 2012 Social impact assessment: The state of the art. *Impact Assessment & Project Appraisal* 30(1), 35-44. **http://dx.doi.org/10.1080/14615517.2012.660356**

Franks, D., Fidler, C., Brereton, D., Vanclay, F. & Clark, P. 2009 *Leading Practice Strategies for addressing the Social Impacts of Resource Developments*. St Lucia: Centre for Social Responsibility in Mining, Sustainable Minerals Institute, The University of Queensland. **http://www.csrm.uq.edu.au/docs/Franks_etal_LeadingPracticeSocialImpacts_2009.pdf**

Franks, D. & Vanclay, F. 2013 Social Impact Management Plans: Innovation in corporate and public policy. *Environmental Impact Assessment Review* 43, 40-48. **http://dx.doi.org/10.1016/j.eiar.2013.05.004**

Vanclay, F. 2003 International Principles for Social Impact Assessment. *Impact Assessment & Project Appraisal* 21(1), 5-11. **http://dx.doi.org/10.3152/147154603781766491**




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## Social impacts are everything that affect people

The *International Principles for Social Impact Assessment* considers that social impacts include all the issues associated with a planned intervention (i.e. a project) that affect or concern people, whether directly or indirectly. Specifically, a social impact is considered to be something that is experienced or felt in either a perceptual (cognitive) or a corporeal (bodily, physical) sense, at any level, for example at the level of an individual person, an economic unit (family/household), a social group (circle of friends), a workplace (a company or government agency), or by community/society generally. These different levels are affected in different ways by an impact or impact-causing action.

Because 'social impact' is conceived as being anything linked to a project that affects or concerns any impacted stakeholder group, almost anything can potentially be a social impact so long as it is valued by or important to a specific group of people. Environmental impacts, for example, can also be social impacts because people depend on the environment for their livelihoods and because people may have place attachment to the places where projects are being sited. Impacts on people's health and wellbeing are social impacts. The loss of cultural heritage, important habitats or biodiversity can also be social impacts because these are valued by people. SIA therefore should address everything that is relevant to people and how they live. This means that SIA cannot start with a checklist of potential impacts, but must identify the social impacts from an awareness of the project and an understanding of how the project will affect what is important to the project's stakeholders. Nevertheless, Box 1 gives some sense of what social impacts are.

### BOX 1: What are social impacts?

Social impacts are changes to one or more of the following:

- people's way of life – that is, how they live, work, play and interact with one another on a day-to-day basis;
- their culture – that is, their shared beliefs, customs, values and language or dialect;
- their community – its cohesion, stability, character, services and facilities;
- their political systems – the extent to which people are able to participate in decisions that affect their lives, the level of democratisation that is taking place, and the resources provided for this purpose;
- their environment – the quality of the air and water people use; the availability and quality of the food they eat; the level of hazard or risk, dust and noise they are exposed to; the adequacy of sanitation, their physical safety, and their access to and control over resources;
- their health and wellbeing – health is a state of complete physical, mental, social and spiritual wellbeing and not merely the absence of disease or infirmity;
- their personal and property rights – particularly whether people are economically affected, or experience personal disadvantage which may include a violation of their civil liberties;
- their fears and aspirations – their perceptions about their safety, their fears about the future of their community, and their aspirations for their future and the future of their children.

**Source:** Vanclay, F. 2003 International Principles for Social Impact Assessment. *Impact Assessment & Project Appraisal* 21(1), 5-11. **http://dx.doi.org/10.3152/147154603781766491**

An important conceptual point is the differentiation between a social change process and a social impact. Not all change-inducing processes in a community necessarily cause social impacts. For example, a modest increase in population is not necessarily a negative social impact. In many circumstances, it may be a benefit leading to economic growth and social development. On the other hand, an unplanned, rapid, large increase in population associated with a project (influx) can create many social impacts. The issue for SIA is how to ensure that the process of in-migration is anticipated, prepared for, and managed adequately to minimize negative impacts and maximize potential benefits.

While SIA is sometimes described as being a social form of environmental impact assessment, there are many differences. For example, the environmental impacts tend only to occur when the first sod of soil is turned, whereas social impacts can happen the moment there is a rumour that something might happen. Rumour leads to speculation and speculative behaviour. In some situations, e.g. a socially-undesirable factory or other locally-unwanted land use, rumour may also promulgate and amplify people's fears and anxieties, whether or not the rumour has any foundation, and whether or not the project actually eventuates. Fear and anxiety, like all perceived impacts, are real social impacts that people experience, and they should not be dismissed, but should be managed effectively.



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The extent and effectiveness of the project's community engagement has a huge bearing on the amount of fear and anxiety generated. The extent of social impacts experienced is largely contingent on contextual factors such as the genuineness of the engagement mechanisms used, and the extent to which the views of all stakeholders were considered and reflected in the various reports and mitigation actions.

Social impacts can also be created by projects that raise false expectations in a community, either by project staff inappropriately knowingly promising things that will not eventuate, or inadvertently through the poor management of expectations and allowing rumours to escalate expectations. For example, it is important for project developers to be realistic about the number and type of jobs likely to be available to local people. Communities can feel 'ripped-off' when the benefits they anticipated receiving from a project do not eventuate. This contributes to a lack of trust in the company and a loss of social licence.

As discussed later in this document (in Task 10), social impacts are rarely singular cause-effect relationships. There are complex patterns of intersecting impact pathways. Health, wellbeing and social outcomes are always multi-factorial. For example, physical changes to habitats created by the project can change the ecology of disease organisms, and changes to living arrangements and lifestyles can change exposure patterns to vector organisms (such as mosquitoes), thus increasing morbidity and perhaps mortality. Changing work patterns (especially with rotating shiftwork and/or long rosters) can lead to health effects not only to the worker, but also on the worker's spouse and children. Sleep disorders, depression, alcohol and substance abuse and family violence are all associated with shiftwork.

Another important understanding is that projects tend to always cause local inflation. This can cause serious ruptures between people who work for the project and those who don't. While project workers are paid wages which typically account for the rate of inflation (and contribute to it), other people experience the rising costs without the benefit of additional income. Thus, projects invariably increase inequality in a community, which is one reason why it is really important for projects to contribute to local social investment initiatives. In boomtown communities, the pull of the project may mean that no workers are available for the low paid service jobs. Poaching of staff from other sectors, including government, is also a major problem creating a high turnover in staff and a lack of capacity.

**For more information** on different types of social impacts, refer to:


Fehr, R., Viliani, F., Nowacki, J. & Martuzzi, M. (eds) 2014 *Health in Impact Assessments: Opportunities not to be missed*, Copenhagen: World Health Organisation Regional Office for Europe. **http://www.euro.who.int/health-in-IA**

Harris-Roxas, B. et al. 2012 Health Impact Assessment: The state of the art. *Impact Assessment and Project Appraisal* 30(1), 43-52, 2012. **http://dx.doi.org/10.1080/14615517.2012.666035**

ICMM 2010 *Good Practice Guidance on Health Impact Assessment*. **http://www.icmm.com/document/792**

IFC 2009 *Introduction to Health Impact Assessment*. Washington, DC: International Finance Corporation. **http://commdev.org/introduction-health-impact-assessment**

IFC 2009 *Projects and People: A Handbook for Addressing Project-Induced In-migration*. Washington, DC: International Finance Corporation. **http://commdev.org/files/2545_file_Influx.pdf**

Petkova, V. et al. 2009 Mining developments and social impacts on communities: Bowen Basin case studies. *Rural Society* 19(3), 211-228. **http://dx.doi.org/10.5172/rsj.19.3.211**

Vanclay, F. 2002 Conceptualising social impacts. *Environmental Impact Assessment Review* 22(3), 183-211. **http://dx.doi.org/10.1016/S0195-9255(01)00105-6**

Vanclay, F. 2012 The potential application of Social Impact Assessment in integrated coastal zone management. *Ocean & Coastal Management* 68, 149-156. **http://dx.doi.org/10.1016/j.ocecoaman.2012.05.016**

Vanclay, F. (ed.) 2014 *Developments in Social Impact Assessment*. Cheltenham: Edward Elgar.

## Social Impact Assessment & Management and Social Performance

Social Impact Assessment (SIA) arose alongside Environmental Impact Assessment (EIA) in the early 1970s primarily as a regulatory tool. Over time, there has been a steady evolution in how SIA is practiced. As interest in SIA grew, a professional community of SIA practitioners developed, forming a discourse around SIA. Like all professional fields of practice, the understanding of the topic has evolved within that discourse. The most important change that has occurred is increasing awareness that addressing the social impacts requires the active management of social issues from the very beginning of a project long before regulatory approval is needed. Another important change is the increasing realisation all round that communities don't want to have project impacts thrust on them, they want to be active partners in co-development and they want to benefit from private sector projects. Shared value is therefore an important consideration. A further realisation is that the regulators and monitoring authorities of today are not just government agencies, but include local and global NGOs (especially watchdog NGOs), international industry associations, the finance and insurance industries, and project-affected communities themselves. While national legislation remains important, it is the international industry associations (e.g. ICMM, IPIECA, International Hydropower Association) and financial institutions (IFC, Equator Principles banks) that now take the lead role in setting standards. Projects that do not meet these international standards may not be successful in gaining project financing or insurance. Projects that do not meet international expectations may be subjected to protest actions, and may face legal challenges and other activist pressure. All this means that projects have to gain and maintain their (social) licence to operate from many stakeholders, each with differing and not necessarily complementary interests, rather than from a singular government regulatory agency.

This change in the discourse and practice of SIA has meant that SIA is now seen in much broader terms than just being the identification of a set of social impacts and the submission of a document to gain regulatory approval. SIA now covers a wide variety of tasks (see below) associated with the interaction between a company/project and its local communities. In the corporate world, this full set of activities is often called social performance, to separate it from the specific task of gaining regulatory approval.

The management of the social issues of projects and therefore the full span of work of SIA practitioners potentially includes the following activities. Note, however, that these tasks are not all done at the same time and what a specific SIA practitioner should do in a specific case will depend on the particular context.

- Undertake an ex-ante assessment of likely social impacts
- Liaise with the EIA team (and any other assessment teams) to ensure that the social aspects of environmental and biodiversity impacts and the environmental and biodiversity impacts of social changes are considered in the impact assessments and management plans
- Compile a community profile (i.e. a description of the local social context)
- Construct a social baseline relevant for decision-making and documenting social changes (i.e. collect data for key social variables to document the pre-impact state)
- Identify and implement changes to the project and undertake other actions to mitigate social impacts
- Plan the resettlement and/or compensation for people who will experience economic displacement in instances where there is no alternative
- Prepare a Resettlement Policy Framework, Resettlement Action Plan, Livelihood Restoration and Enhancement Plan and ensure that these are integrated into the project development plans and timeframes
- Undertake human rights due diligence and human rights impact assessments, involving human rights experts as necessary
- Identify ways of enhancing the benefits of the project
- Identify stakeholders, and map their interests, relationships, and potential two-way project-stakeholder impacts
- Facilitate genuine community engagement processes consistent with the spirit of free, prior and informed consent
- Where Indigenous communities are involved, assist in processes to comply with formal Free, Prior and Informed Consent requirements
- Assist affected communities in understanding what the likely social impacts of a proposed project might mean for them
- Enhance local content and local procurement arrangements
- Monitor social issues
- Design and implement social investment actions



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- Establish appropriate compensation mechanisms
- Design and implement grievance mechanisms
- Negotiate Impacts & Benefits Agreements
- Develop Social Impact Management Plans
- Prepare documentation for a regulatory authority
- Identify issues and/or obligations for addressing the management of social impacts to be included in contracts with project subcontractors
- Prepare performance standard compliance documentation for a financial institution (World Bank, IFC, another multilateral development bank, or an Equator Principles bank)
- Undertake a due diligence assessment or audit of social performance for a community, NGO or for a financial institution
- Assist in closure planning.

SIA (or at least social performance), in the form of the management of social issues, thus covers a very wide-ranging set of activities and is applicable to the whole of project life. In actual practice, the tasks of managing the social issues are undertaken by a wide range of people. Therefore, responsibility for thinking about and managing social issues needs to be a core part of the corporate culture and the workplace culture of projects, and just like safety, should be everyone's business. Nevertheless, there needs to be a project person with responsibility for social performance. Many of the social performance tasks are outsourced to consultants, such as SIA practitioners. Each particular consultancy contract is unlikely to require addressing all the tasks implied above or that are addressed in this document. However, this document does provide guidance on addressing the social issues at all phases of the project. Different parts of the document will be relevant to different people at different times.

**For more information** on the components of SIA, see the rest of this document and also refer to:


Esteves, A.M., Franks, D. & Vanclay, F. 2012 Social impact assessment: The state of the art. *Impact Assessment & Project Appraisal* 30(1), 35-44. **http://dx.doi.org/10.1080/14615517.2012.660356**

Esteves, A.M. & Vanclay, F. 2009 Social Development Needs Analysis as a tool for SIA to guide corporate-community investment: Applications in the minerals industry. *Environmental Impact Assessment Review* 29(2), 137-145. **http://dx.doi.org/10.1016/j.eiar.2008.08.004**

Franks, D. & Vanclay, F. 2013 Social Impact Management Plans: Innovation in corporate and public policy. *Environmental Impact Assessment Review* 43, 40-48. **http://dx.doi.org/10.1016/j.eiar.2013.05.004**

## Social Impact Assessment is relevant to all project phases

SIA is the process of managing the social issues of projects. It adjusts to the varying social concerns and issues at different points in the project cycle. Figure 1 depicts a typical project cycle and identifies the potential role for SIA at each phase. The important point is that at each project phase, there is a role for SIA. While the project cycle is usually depicted as a linear process, the reality is not so straight forward. Projects do not necessarily transition smoothly from phase to phase, and may become stalled at a certain phase, or may be sent back to earlier stage.

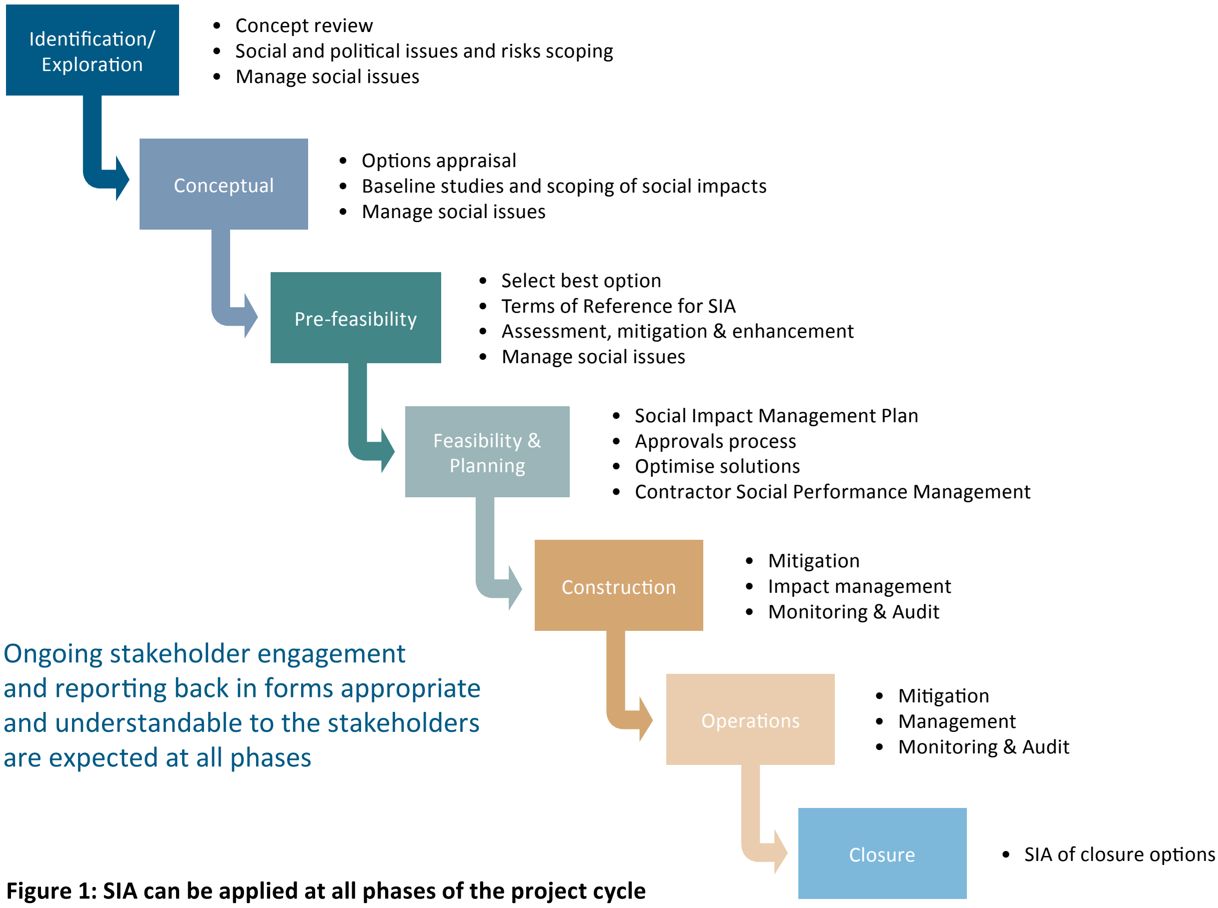


**Figure 1: SIA can be applied at all phases of the project cycle**

## Who commissions, who uses, and who does Social Impact Assessments?

SIA can be used by a wide range of stakeholders for a wide range of purposes. In the conventional (EIA) model, although the exact procedure varied by jurisdictional setting, typically regulatory agencies required proponents to commission private consultancy firms to produce an SIA/EIA report which had to meet regulatory agency stipulations, and sometimes a formal peer review process. Typically there would be a public comment period, with the consultant having to respond to the public comments. Various NGOs might take legal action if there was a view that the report was substandard. This regulatory model was not very effective because it was resented by proponents and often not taken seriously, was too late in the project planning process to influence the project, and because of the lack of follow-up by regulatory agencies in relation to any permitting conditions. SIA has been far more effective in influencing project design and enhancing outcomes for communities when it has been a key part of the proponent's planning and risk management processes. Even though most SIA consultants are advocates for communities, there is still an evident power imbalance between the proponent and the community. One model that can be applied in contexts with low trust between the proponent and the community is for the proponent to provide funding to the host communities so that they can commission their own impact assessment consultants. The community-based SIA would assist in informing the community. Arguably this model would support a negotiation process that was meant to be consistent with the spirit of free, prior and informed consent.



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## The phases and tasks of Social Impact Assessment

There are many different ways of depicting the tasks involved in an SIA process. Some show SIA as being closely related to EIA, others depict SIA as being similar to a social version of an environmental management system by highlighting the iterative nature of the process and seeing it as a process of continuous improvement. Here, the SIA process is depicted as comprising four phases (see Figure 2) that are somewhat sequential, but which also overlap. Through data collection and analysis, SIA is a learning process, and consequently initial assumptions and preliminary understandings may need to be modified in the light of new information, so there needs to be an iterative process of validation and update informed by an on-going process of consultation with project proponents and other stakeholders, especially from impacted communities.

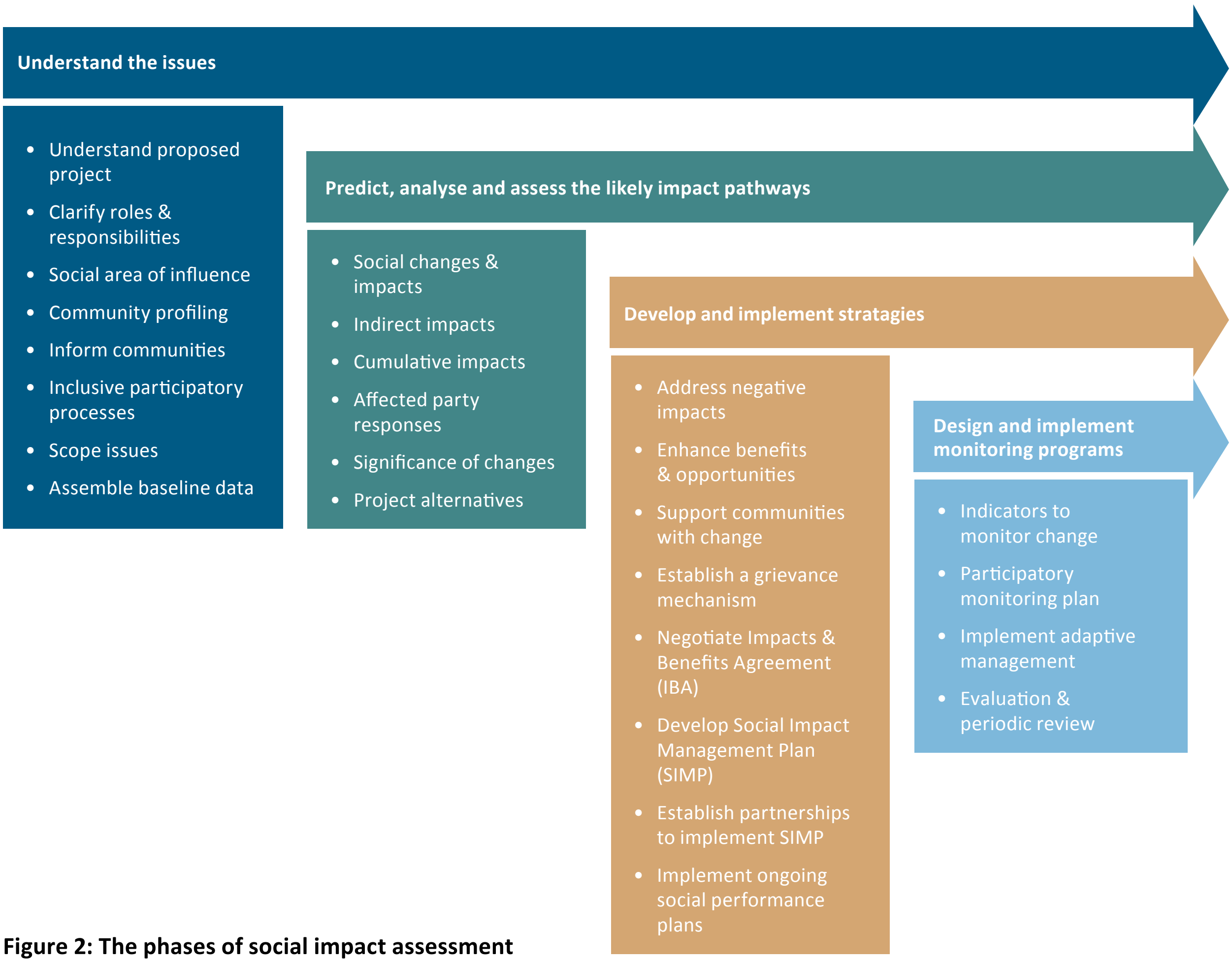


**Figure 2: The phases of social impact assessment**

Good practice SIA essentially involves undertaking all the tasks listed in Box 2. These tasks are presented in approximately chronological order, but it should be noted that they inform each other, and as information is accumulated in the SIA, decisions made earlier in the process about the scope, area or influence, and stakeholders may need to be re-assessed as new information becomes discovered. It is thus an iterative process. The list of tasks comprising SIA are presented here, and are discussed in detail later in this document.

## BOX 2: The 26 tasks that comprise social impact assessment

**Phase 1: Understand the issues**

1. Gain a good understanding of the proposed project, including all ancillary activities necessary to support the project's development and operation.
2. Clarify the responsibilities and roles of all involved in or associated with the SIA, including relationships to the other specialist studies being undertaken, and establish what national laws and/or international guidelines and standards are to be observed.
3. Identify the preliminary 'social area of influence' of the project, likely impacted and beneficiary communities (nearby and distant), and stakeholders.
4. Gain a good understanding of the communities likely to be affected by the project by preparing a Community Profile which includes: (a) a thorough stakeholder analysis; (b) a discussion of the socio-political setting; (c) an assessment of the differing needs, interests, values and aspirations of the various subgroups of the affected communities including a gender analysis; (d) an assessment of their impact history, i.e. their experience of past projects and other historical events; (e) a discussion of trends happening in those communities; (f) a discussion of the assets, strengths and weaknesses of the communities; and (g) optionally the results of an opinion survey. This task is typically called profiling.
5. Fully inform community members about: (a) the project; (b) similar projects elsewhere to give them a sense of how they are likely to be affected; (c) how they can be involved in the SIA; (d) their procedural rights in the regulatory and social performance framework for the project; and (e) their access to grievance and feedback mechanisms.
6. Devise inclusive participatory processes and deliberative spaces to help community members: (a) understand how they will be impacted; (b) determine the acceptability of likely impacts and proposed benefits; (c) make informed decisions about the project; (d) facilitate community visioning about desired futures; (e) contribute to mitigation and monitoring plans; and (f) prepare for change.
7. Identify the social and human rights issues that have potential to be of concern (i.e. scoping).
8. Collate relevant baseline data for key social issues.

**Phase 2: Predict, analyse and assess the likely impact pathways**

9. Through analysis, determine the social changes and impacts that will likely result from the project and its various alternatives.
10. Carefully consider the indirect (or second and higher order) impacts.
11. Consider how the project will contribute to the cumulative impacts being experienced by the host communities.
12. Determine how the various affected groups and communities will likely respond.
13. Establish the significance of the predicted changes (i.e. prioritise them).
14. Actively contribute to the design and evaluation of project alternatives, including no go and other options.

**Phase 3: Develop and implement strategies**

15. Identify ways of addressing potential negative impacts (by using the mitigation hierarchy).
16. Develop and implement ways of enhancing benefits and project-related opportunities.
17. Develop strategies to support communities in coping with change.
18. Develop and implement appropriate feedback and grievance mechanisms.
19. Facilitate an agreement-making process between the communities and the developer leading to the drafting of an Impacts & Benefits Agreement (IBA).
20. Assist the proponent in facilitating stakeholder input and drafting a Social Impact Management Plan (SIMP) which puts into operation the benefits, mitigation measures, monitoring arrangements and governance arrangements that were agreed to in the IBA, as well as plans for dealing with any ongoing unanticipated issues as they may arise.
21. Put processes in place to enable proponents, government authorities and civil society stakeholders to implement the arrangements implied in the SIMP and IBA, and develop and embed their own respective management action plans in their own organizations, establish respective roles and responsibilities throughout the implementation of those action plans, and maintain an ongoing role in monitoring.
22. Assist the proponent in developing and implementing ongoing social performance plans that address contractor obligations implied in the SIMP.

**Phase 4: Design and implement monitoring programs**

23. Develop indicators to monitor change over time.
24. Develop a participatory monitoring plan.
25. Consider how adaptive management will be implemented and consider implementing a social management system.
26. Undertake evaluation and periodic review (audit).



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## Doing Social Impact Assessment is good business and good for business

While the goal of SIA is to ensure better development outcomes for people and communities, this will be best achieved when companies and other actors see the benefits to themselves of embracing SIA. Thus, to achieve the objectives of SIA, both of minimising harm and maximising benefits to the affected communities, whether SIA is legally required or not, SIA will need to be aligned with (and influence) corporate processes and time scheduling, and companies will need to see the value of SIA if they are to be fully committed to doing SIA properly and implement recommended mitigation and enhancement strategies in good faith.

Even though in certain jurisdictions SIA may be a legal requirement, the moral or normative argument is that communities expect companies to do proper SIA and therefore SIA is part of the social responsibility obligations of companies – doing SIA is the right thing to do! However, while this argument has certain altruistic justification, it does not necessarily convince those corporates who believe their duty is to maximise returns to their shareholders while remaining within the law. Similarly, the more self-interested argument that doing SIA properly is necessary for companies to earn their social licence to operate does not necessarily fully convince corporate executives either, because in this way of thinking, SIA is seen only as cost/outlay that is needed to obtain social approval and permission. As a cost, attempts will always be made to reduce expenditure especially because there is no perceived or easily-substantiable direct connection between the cost of SIA and its return in the form of social approval. In contrast, we argue that doing SIA properly should not be seen as a cost but an investment in risk management. It will reduce a company's likely future expenditures by identifying potential issues and thereby reduce likely future costs in the form of litigation, delays to approval, costs in the form of managing protest actions or addressing violence against staff and/or property, and business losses from reputational harm. Reducing risk also leads to reduced costs of capital and hence increases shareholder value.

SIA has the potential to identify local knowledge that could guide project siting decisions and reduce cost to companies that comes from poor siting decisions. While much information can be gained from technical surveys and model predictions, they are no substitutes for the lived experiences of local people. Having the positive support of local communities can greatly assist project development.

SIA can assist in the establishment of a local employment and supply base. Having capable employees and suppliers close to projects reduces the costs of transport, logistics, and inventory and reduces supply chain inefficiencies. Supporting the development of thriving and healthy communities that are attractive places to live and work increases the attraction and retention of quality employees. In addition, demands for increased social investment and higher taxes on the sector might be reduced if communities and governments believe that companies are making a valuable contribution to their communities. Thus there are many reasons why doing SIA properly makes good business sense. SIA adds value to all business drivers (see Figure 3).

**For more information** on the benefits to business of doing social impact assessment, refer to:

Davis, R. & Franks, D.M. 2014 *Costs of Company-Community Conflict in the Extractive Sector.* Corporate Social Responsibility Initiative Report, John F. Kennedy School of Government, Harvard University, Cambridge, MA. **http://www.hks.harvard.edu/m-rcbg/CSRI/research/Costs%20of%20Conflict_Davis%20%20Franks.pdf**

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IFC 2010 Strategic Community Investment: *A Good Practice Handbook for Companies Doing Business in Emerging Markets.* Washington, DC: International Finance Corporation. **http://www.ifc.org/wps/wcm/connect/f1c0538048865842b50ef76a6515bb18/12014complete-web.pdf?MOD=AJPERES**

Sohn, J. (ed.) 2007 *Development without Conflict: The Business Case for Community Consent.* Washington, DC: World Resources Institute. **http://www.wri.org/publication/development-without-conflict**

SociaLicense.com 2014 website **http://www.socialicense.com**

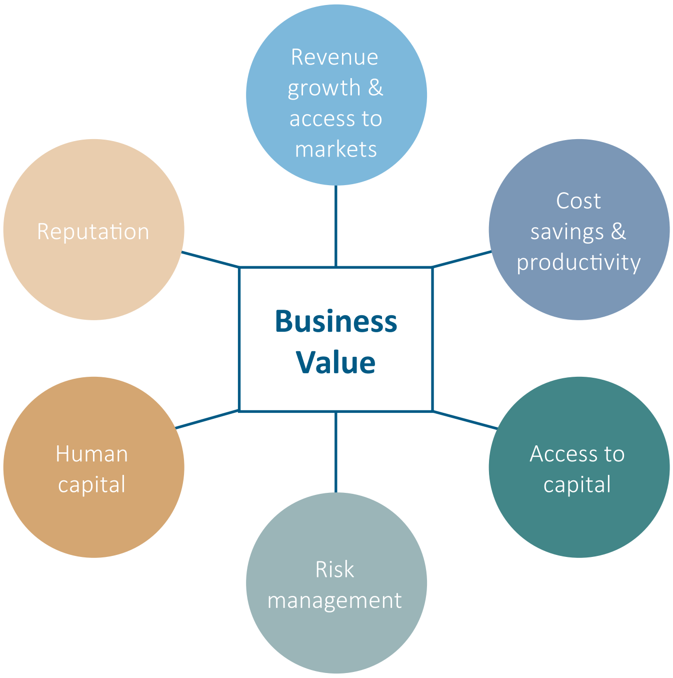


**Figure 3: Schematic representation of the business value drivers to which SIA adds value**

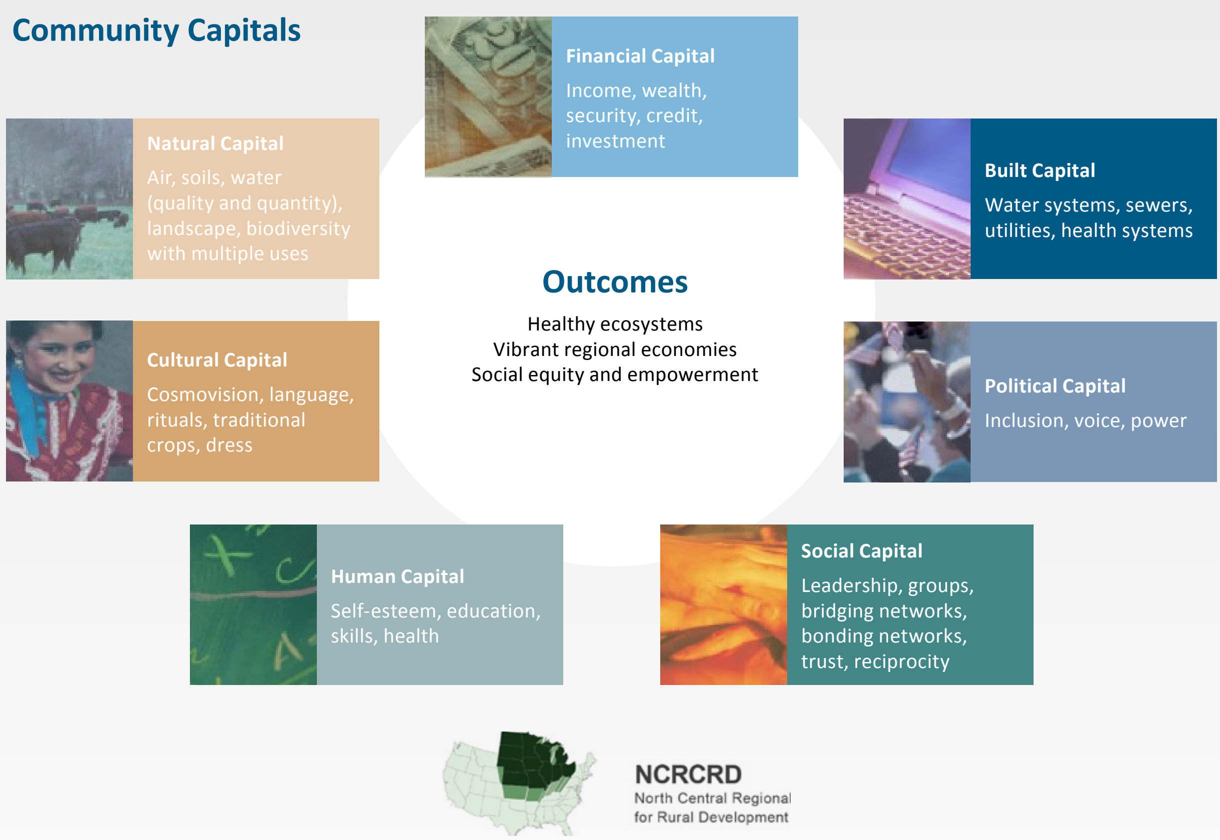


**Figure 4: Community Capitals**

**Source:** Cornelia Butler, North Central Regional Center for Rural Development (used with permission).



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## The goal of all projects should be sustainable social development

Where companies, especially foreign multi-national corporations, are granted a legal permit to operate within a country, they also need to seek and maintain a social licence to operate. To gain a social licence they need to make a positive contribution to the country and, more importantly, to the local communities in which they operate above and beyond any taxes and royalties they might be required to pay. Their entitlement to access profit-making opportunities comes from the opportunities companies provide and the investments they make that contribute to social development in the host country and in their local communities. In return, they are seen as trusted, socially-responsible companies, and as 'developer of choice', which brings reputational benefits and access to markets elsewhere – very much part of the shared value proposition.

To gain and maintain a genuine social licence requires that the project think about its contribution to social development. Social development means more than just providing a few jobs and providing funding for a new school building or swimming pool, it requires that the project partner with the local communities in being a force for positive social change and beneficial social development. Social development should be a participatory process of planned social change designed to improve the wellbeing of the community as a whole and especially of the vulnerable, disadvantaged or marginalised groups within a region. Rather than being about benefits to individuals per se, social development is more about facilitating change in institutions and society to reduce social exclusion and fragmentation, to promote social inclusion and democratisation, and to build capacity in institutions and governance. Social development looks beyond problems and deficiencies to focus on increasing the capabilities of people and institutions and how they can be strengthened. However, companies should be clear and targeted in their interventions to ensure that they do not absorb or usurp the role and responsibilities of local authorities.

Social investment refers to the financial and in-kind contributions a project makes to the local community for social development. Ideally these resources should not be wasted on non-sustainable, impractical wishlist items, but should contribute to the achievement of social development outcomes. This implies that there should be an assessment process used to select and prioritise social investment options. The term, strategic social investment, is used when, in addition to supporting social development outcomes for the local community, there is a clear business case to the company in making the funds available. Contributing to training programs that build the skills of the local workforce so that they can supply labour or services to the project is a clear example of shared value.

The social development goals that will be appropriate will vary with the particular context of application. Identifying these goals should be a participatory process led by the community. In general terms, the United Nations Sustainable Development Goals (see Figure 5) would be worthwhile matters to consider. Identifying and assessing possible options for social investment also requires thinking about the strengths and weaknesses within local communities. A commonly-used framework to assist is the 'community capitals approach' (sometimes known as the pyramid model), which underpins the Sustainable Livelihoods Approach (and its variants) (see Box 3 and Figure 4). The Sustainable Livelihoods Approach considers the capabilities, livelihood resources (assets, capitals) and livelihood strategies (activities) people undertake to make their living and conduct their way of life. At the heart of the model is the notion that all community resources or assets can be represented as a set of capitals. The assessment of social investment strategies can consider these capitals and how strengthening one or more of these capitals might increase the overall wellbeing in the community.



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## Sustainable Development Goals


**Figure 5: Sustainable Development Goals**

**Source:** United Nations Sustainable Development Goals website, **https://sustainabledevelopment.un.org/**



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## BOX 3: Types of capital or asset

*Note: There are multiple forms of capital (assets, resources) and many different ways of grouping and defining them. What is included should depend on the context of application. The individual capitals are meant to be metaphors and used generically rather than being strictly defined and interpreted narrowly. The concept of the capitals can be applied at different levels of analysis – it can be used to apply to an individual, to a household, a local community, or region. The capitals approach was originally developed in terms of understanding the livelihood strategies of individuals living in impoverished rural communities in developing countries. It has now been applied in a wide range of situations.*

**Natural capital:** includes the stocks and flows of environmentally-provided assets (i.e. ecosystem services) such as food and agricultural resources, forest resources, mineral reserves, soil, water, wetlands and fish stocks.

**Physical capital** (*also known as produced, manufactured or built capital*): comprises the stock of equipment, physical plant (e.g. factories), infrastructure (e.g. roads, airports, hospitals, schools), and other productive resources owned by individuals, the business sector, or the country itself, as well as the management systems needed to make them work.

**Financial capital:** the financial resources available to people, such as their savings and access to credit. It also notes any debts or mortgage they may have.

**Human capital:** includes the levels of knowledge and skill, formal education, health and nutrition of individuals, as well as their motivation and aptitude.

**Social capital:** sometimes simply defined as only social networks and trust, it also includes the social rules, norms, obligations, and reciprocity arrangements embedded in social relations, social structures, and the society's institutional arrangements.

**Political or Institutional capital:** refers to the existence and effective functioning (i.e. capacity) of the society's governance mechanisms – to the governance institutions themselves and to the standards, rules, regulations they apply and their enforcement.

**Cultural and Spiritual capital:** includes the way people know the world and their place within the world, as well as how they act within it. It also refers to the extent to which the local culture, traditions and language, etc promote or hinder wellbeing, social inclusion and social development. Spiritual capital assists in maintaining a balance across the different capitals and in remaining in touch with deeply-held values and the things that give meaning to life. Cultural capital influences what voices are heard and listened to, which voices have influence in what areas, and how creativity, innovation and influence emerge and are nurtured.

**For more information** on social development and social investments, refer to:


Community Toolbox online resource: **http://ctb.ku.edu/en/table-of-contents**

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Esteves, A.M. & Vanclay, F. 2009 Social Development Needs Analysis as a tool for SIA to guide corporate-community investment: Applications in the minerals industry. *Environmental Impact Assessment Review* 29(2), 137-145. **http://dx.doi.org/10.1016/j.eiar.2008.08.004**

Flora, C.B. et al. (no date) *Community Capitals: A Tool for Evaluating Strategic Interventions and Projects*. Ames: North Central Regional Center for Rural Development, University of Iowa. **http://wp.aae.wisc.edu/ced/wp-content/uploads/sites/3/2014/01/204.2-Handout-Community-Capitals.pdf**

Hallam, A. 2012 *Scottish Government Investment in Rural Community Development: A Community Capitals Approach.* Edinburgh: Scottish Government. **http://www.scotland.gov.uk/Resource/0038/00389818.pdf**

ICMM 2012 Community Development Toolkit **http://www.icmm.com/community-development-toolkit**

IFC 2010 *Strategic Community Investment: A Good Practice Handbook for Companies Doing Business in Emerging Markets.* Washington, DC: International Finance Corporation. **http://www.ifc.org/wps/wcm/connect/f1c0538048865842b50ef76a6515bb18/12014complete-web.pdf?MOD=AJPERES**

Midgley, J. 2014 *Social Development: Theory and Practice.* Los Angeles: Sage.

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Owen, J. & Kemp, K. 2012 Community development in mining assets, capitals, and resources: Frameworks for corporate community development in mining. *Business & Society* 51(3), 382-408. **http://dx.doi.org/10.1177/0007650312446803**

Pawar, M. & Cox, D. (eds) 2010 *Social Development: Critical Themes and Perspectives.* New York: Routledge.

Porritt, J. 2005 *Capitalism as if the World Matters*. London: Earthscan.

Scoones, I. 1998 *Sustainable Rural Livelihoods: A Framework for Analysis,* IDS Working Paper 72. **http://mobile.opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/3390/Wp72.pdf**

Wang, C. 2012 *A Guide for Local Benefit Sharing in Hydropower Projects*. Washington, DC: World Bank. **https://openknowledge.worldbank.org/handle/10986/18366**

World Bank 2010 *Mining Foundations, Trusts and Funds: A Sourcebook.* Washington, DC: World Bank. **http://siteresources.worldbank.org/EXTOGMC/Resources/Sourcebook_Full_Report.pdf**

## Human rights need to be considered

Human rights are defined by the United Nations as being "universal legal guarantees protecting individuals and groups against actions which interfere with fundamental freedoms and human dignity". They seek to guarantee people's basic needs. The universality principle means that they apply to all people by virtue of being human. Non-discrimination is a central theme in the human rights discourse. This includes recognising that specific groups of rights-holders, especially vulnerable people, women, children, Indigenous peoples, and other marginalised groups, require special attention to be able to enjoy their human rights. Human rights are regarded as being interrelated, inalienable and indivisible, and all human rights are regarded as being equal in status, and all must be observed.

With the adoption of the *United Nations Guiding Principles on Business and Human Rights* (UNGP) in 2011, the corporate responsibility to respect human rights was confirmed. This responsibility requires that companies exercise due diligence to identify and address any adverse human rights impacts with which they are involved. Due diligence is a process by which companies can 'know and show' their respect for human rights. It includes: (1) having a human rights policy commitment in place; (2) assessing impacts on human rights; (3) integrating the findings of the assessment process into corporate management systems, monitoring and tracking performance; and (4) reporting and communicating about the due diligence measures implemented and their effectiveness in identifying and addressing impacts. Importantly, the adverse impacts that companies are expected to identify and address include not only impacts that the company causes or contributes to, but also impacts that are directly linked to a project's operations, products or services through its business relationships. This means that companies must not be complicit in human rights abuses by business-related third parties, and where they become aware of human rights impacts of these third parties, they must exercise leverage or influence to prevent or minimize those impacts. This should be considered as being part of the corporate risk identification and management process. Companies are also expected, as part of human rights due diligence, to put in place or collaborate in appropriate avenues for access to remedy for any human rights abuses with which they are involved. At the project level, this includes having in place a community grievance mechanism that can effectively address any grievances that are raised by community members. A process of continuous improvement in the way companies manage their human rights impacts is also expected.

Principle 12 of the UNGP outlines the minimum standard for human rights observance: "The responsibility of business enterprises to respect human rights refers to internationally recognized human rights – understood, at a minimum, as those expressed in the International Bill of Human Rights and the principles concerning fundamental rights set out in the International Labour Organization's Declaration on Fundamental Principles and Rights at Work". The four principles in the International Labor Organization's (ILO) Declaration of Fundamental Principles and Rights at Work (ILO 1998, online) are: (a) freedom of association and the effective recognition of the right to collective bargaining; (b) the elimination of all forms of forced or compulsory labour; (c) the effective abolition of child labour; and (d) the elimination of discrimination in respect of employment and occupation. The UNGP states that businesses may need to consider additional standards, depending on host and home state circumstances.

Many social impacts can be understood in human rights terms. This includes recognising project-affected individuals and communities as human rights-holders with legal entitlements, including the right of legal redress for impacts on their human rights. Thus when a project creates social impacts, it may also be in breach of its responsibility to respect human rights. This gives extra importance to social impacts, and increases the importance of social impact assessment.

The UNGP emphasise the need for companies to provide effective remedy to victims of human rights impacts connected to the company's activities or operations. Access to remedy is a right in itself guaranteed in the International Covenant on Civil and Political Rights. While potential and actual victims should always be able to have access to legal proceedings, project-level grievance mechanisms can also have an important role to play in the early identification of grievances, avoiding escalation and providing effective solutions.

It is important to realise that rights-holders are supposed to be able to claim their rights. This means that they must be informed about their rights, and know what avenues of redress are available to them. Ensuring that human rights are upheld and that people know and can claim their rights are primarily the duties of government. However, companies can have a role to play in contributing to rights-awareness of their neighbouring communities.

There are differences between a human rights-based approach (HRBA), human rights impact assessment (HRIA), and social impact assessment; and it is the case that in the past, SIA tended not to consider human rights issues in a systematic way. However, with the adoption of the UNGP in 2011, human rights are now part of the suite of international standards applicable to business, therefore best practice SIA should now fully consider human rights issues in all circumstances except where a separate HRIA is being undertaken. To accommodate this inclusion, the skillset of SIA practitioners will need to be expanded to cover all areas relevant to human rights, including labour rights, child labour, forced labour and freedom of association.

**For more information** on human rights, refer to:

United Nations 2011 *Guiding Principles on Business and Human Rights*.
**http://www.ohchr.org/Documents/Publications/GuidingPrinciplesBusinessHR_EN.pdf**

United Nations 2012 *The Corporate Responsibility to Respect Human Rights: An Interpretive Guide.*
**http://www.ohchr.org/Documents/Publications/HR.PUB.12.2_En.pdf**

DIHR & IPIECA 2013 *Integrating human rights into environmental, social and health impact assessments: A practical guide for the oil and gas industry.*
**http://www.ipieca.org/sites/default/files/publications/Integrating_HR_into_environmental_social_and_HIS_0.pdf**

European Commission 2013 *Oil and Gas Sector Guide on Implementing the UN Guiding Principles on Business and Human Rights.* **http://ec.europa.eu/enterprise/policies/sustainable-business/files/csr-sme/csr-oag-hr-business_en.pdf**

Götzmann, N. 2014 *Human rights and impact assessment: Conceptual and practical considerations in the private sector context.* Copenhagen: Danish Institute for Human Rights.
**http://www.humanrights.dk/publications/human-rights-impact-assessment**

International Business Leaders Forum & IFC 2011 *Guide to Human Rights Impact Assessment and Management (HRIAM).* **http://www.ifc.org/hriam**

Kemp, D. & Vanclay, F. 2013 Human rights and impact assessment: clarifying the connections in practice. *Impact Assessment & Project Appraisal* 31(2), 86-96. **http://dx.doi.org/10.1080/14615517.2013.782978**

Rio Tinto 2013 *Why Human Rights Matter*
**http://www.riotinto.com/documents/ReportsPublications/Rio_Tinto_human_rights_guide_-_English_version.pdf**

Shift and Mazars 2015 *UN Guiding Principles Reporting Framework with Implementation Guidance*.
**http://www.ungpreporting.org/**

Taylor, M., Zandvliet, L. & Forouhar, M. 2009 *Due Diligence for Human Rights: A Risk-Based Approach.* Corporate Social Responsibility Initiative Working Paper No. 53. Cambridge, MA: John F. Kennedy School of Government, Harvard University. **http://www.hks.harvard.edu/m-rcbg/CSRI/publications/workingpaper_53_taylor_etal.pdf**

## Indigenous, Traditional, Tribal and other land-connected peoples should be acknowledged and given specific attention

The term 'Indigenous peoples' is widely used as a generic term around the world, even though it is difficult to define and even though some Indigenous groups and other stakeholders (especially in certain regional contexts) prefer a range of largely equivalent terms such as: tribal groups, first peoples, first nations, Aboriginal peoples, ethnic minorities, *adivasi*, traditional peoples; **or** occupational and geographical terms such as hunter-gatherers, fishing communities, reindeer herders, nomads, peasants, hill people; **or** official designations such as scheduled tribes. In some countries, notably many African nations, there is strong opposition to the concept of 'Indigenous' because of its colonial implications. In other countries, especially in Central and South America, definitional issues are made more complex by the existence of Maroons, the descendants of slaves who have established separate communities and over time have developed a unique culture and identity. Further complexities are added by ethnogenesis – a concept that refers to the emergence of groups of people who claim a separate sociocultural heritage differentiated from the broader society in situations where they were not previously recognized. These and other complexities make it difficult to settle on a singular term and define it precisely in a way that makes it universally applicable. Nevertheless, regardless of the specific term used, in around 90 countries of the world there are peoples who have a cultural identity separate to the dominant culture in those countries and who typically have a strong attachment to the land. The United Nations estimates that there are over 370 million such individuals around the world, speaking over 4,000 languages. For the sake of convenience, in this document (and as in most international documents) they are generically called 'Indigenous peoples', although more specific terms are used in particular situations.

Although grouped under one overarching term, there is considerable diversity amongst Indigenous peoples, not only in language and culture, but also in fundamental beliefs, governance structures, cosmologies, ways of living, and livelihoods. Nevertheless, Indigenous peoples typically have several (but not necessarily all) of the following characteristics:

- an individual self-identification as an Indigenous person (or at least as a member of a specific cultural grouping) and acceptance of this claim by other people who also so identify;
- a strong link to land, territories and related natural resources;
- distinctive social, economic and/or political systems;
- a distinct culture (or at least a set of values and beliefs), and possibly a unique language;
- comprise a social grouping that is not part of the dominant groups within the society in which they live;
- a resolve to maintain and reproduce their ancestral environments and systems as distinctive peoples and communities.

Because of their special ties to the land, Indigenous peoples are typically very vulnerable to activities that impact the lands and natural resources on which they depend and/or to which they are culturally attached. Indigenous peoples are over-represented amongst the world's poor and have lower positions on most health and wellbeing indicators. There are two key international agreements pertaining to Indigenous peoples: the International Labour Organization's 1989 Convention concerning Indigenous and Tribal Peoples in Independent Countries (C169); and the 2007 United Nations Declaration on the Rights of Indigenous Peoples. These documents emphasise that Indigenous peoples are entitled to the same basic human rights as all other peoples of the world, however, because of Indigenous peoples' special connection to the land and their vulnerability, they deserve special consideration to ensure their rights are respected. These documents also refer to the notion of collective rights. While most human rights accrue to individuals by virtue of their being human, collective rights are intended to protect those characteristics of Indigenous peoples that can only arise from being a member of a group. These collective rights typically ensure that Indigenous peoples can maintain their cultures, exercise their right of self-determination, and survive as distinct social and cultural groups. The collective right of self-determination provides that Indigenous peoples can freely determine their political status and freely pursue their economic, social and cultural development. A related right is that they have the right to live in freedom, peace and security as a distinct group and not be subjected to any action that seeks to, or could, obliterate their identity as a distinct cultural group.

An important concept in these two documents is that of 'free, prior and informed consent' (FPIC). FPIC is a principle that embodies respect for the right to self-determination of Indigenous peoples and provides a process to ensure effective recognition, respect and protection of that right. In essence, it is a principle about respectful engagement with communities. Although FPIC first arose in the Indigenous rights discourse, some commentators suggest it is an appropriate principle to apply to engagement with all communities, especially if projects are to gain a social licence to operate. **Free** means that there must be no coercion, intimidation, harassment or manipulation by companies or governments, and that should a community say 'no' there must be no retaliation or threat of retaliation.

**Prior** means that consent should be sought and received before any activity on community land is commenced and that sufficient time is provided for adequate consideration by any affected communities. **Informed** means that there must be full disclosure by project developers of their plans in a language and format acceptable to the affected communities, and that each community is able to have a reasonable understanding of what those plans will likely mean for them, including of the social impacts they will experience if the project proceeds. Capacity building, and the time taken for such capacity building may be necessary to ensure that the informed criterion is met. **Consent** means that communities have a real choice, that they can say yes if there is a good flow of benefits and development opportunities to them, or they can say no if they are not satisfied with the deal, and that there is a workable mechanism for determining whether there is widespread consent in the community as a whole and not just a small elite group within the community.

While the spirit of FPIC is a worthy philosophy of respect, its implementation in law and practice raises challenges for projects, communities and government stakeholders alike, specifically in terms of how consent can be established. The IFC emphasises that unanimous consent is not required, only that there needs to be "broad community support". Also, perhaps in contradiction to common sense understandings, consent tends not to be interpreted as having the power of veto. Some international organisations consider that consent is an objective of FPIC rather than an absolute requirement. Despite the legal semantics of FPIC, treating communities with respect should entail according communities (Indigenous and otherwise) the ability to exercise the spirit of FPIC and to have the ability to say no to a proposed project. It can hardly be regarded as a fair and balanced discussion if one party enters negotiation having no intention of respecting the other party's right to say no, and in most cases having a legal right of compulsory acquisition.

Treating Indigenous peoples with respect would imply observance of the following points:

- Acknowledging their existence and recognising their rights as Indigenous persons, even where this is not recognised in national law;
- Fully observing the spirit of free, prior and informed consent, including respecting their ability to say no;
- Appointing an Indigenous Liaison Officer and creating an ongoing engagement mechanism for interacting with Indigenous peoples that is appropriate in the particular cultural context;
- Ensuring equal opportunities and non-discrimination in the workplace;
- Promoting cultural sensitivity amongst all company and contractor staff and embedding a culture of cultural sensitivity;
- Accommodating cultural needs by, for example, being flexible in how staffing arrangements are implemented to ensure that all staff and local peoples can maintain their cultural and religious traditions;
- Promoting the acceptance of, and celebrating the different cultures of local peoples and amongst company staff and contractors;
- Respecting traditional livelihoods and enabling co-existence;
- Respecting the tangible and intangible cultural heritage of Indigenous peoples, including sacred sites, and having a proactive approach to identifying and protecting them;
- Respecting and championing the legal and customary land-rights of Indigenous peoples (see Box 4);
- Acknowledging the existence of customary law and recognizing and incorporating traditional justice into community grievance mechanisms and elsewhere, as appropriate;
- Developing local content arrangements in such a way that local Indigenous peoples are able to have a chance at being a supplier of workforce, goods and services to the project, and assisting them in doing so;
- Accepting traditional knowledge and cosmologies alongside western science and including traditional knowledge considerations in impact assessments and other scientific reports;
- Protecting and respecting Indigenous Intellectual Property;
- Paying appropriate royalties and/or rent to Indigenous traditional owners of lands and resources that are being utilised by the project;
- Developing or selecting indicators of health and wellbeing that represent the values, interests and worldviews of the particular Indigenous group(s) affected by the project when designing baselines and monitoring programs;
- Treating Indigenous peoples as true partners rather than as mere stakeholders, and informing and involving them in all decisions and processes that may affect their rights or interests, just as one would treat any other business partner.

Respect for Indigenous peoples means doing things with them, not for them. There is no place for patronising behaviour or attitudes. An engagement based on a philosophy of co-learning and co-management is appropriate to ensure their rights and interests are fully considered in the assessment of impacts, development of mitigation and enhancement measures and social investment programs, and that their free, prior and informed consent is gained before any action is undertaken whether for the project, for their benefit, or at their behest. Indigenous decision making is often on a consensual basis, or at least on the basis of providing an opportunity for all people to contribute. Therefore, sufficient time must be provided to allow such processes to take place in their own time without duress or unreasonable time pressure. While a notion of empowerment of vulnerable groups is widely prevalent in development circles and in SIA (e.g. in the *International Principles for Social Impact Assessment)*, the way this is actually effected needs to be done cautiously, so as not to be patronising. In addition, care must be taken to ensure that empowerment processes do not exacerbate or lead to inequality within a group, or to other divisions or conflict.

One dimension of respect for Indigenous peoples is acknowledgement of the past harm they have experienced from colonialism, recent history, and even from previous projects. Saying sorry for that harm is not necessarily an admission of guilt or culpability, and can go a long way to demonstrating respect and understanding (see Box 5).

### BOX 4: Example of benefit creation for Indigenous Peoples

A major pipeline project in South America was committed to the recognition of Indigenous peoples, respect for their rights, and in making them beneficiaries of the project even though they would be only temporarily impacted by the project. As a voluntary action, the project developers established a land titling program that enabled the local Indigenous peoples along the pipeline route to secure formal legal title to their lands (something they did not have before). In addition, funds were provided at the national level to facilitate the consolidation of native territories, and to support land claims.

### BOX 5: Example of demonstrating respect towards Indigenous peoples: a 'Welcome to Country' ritual

In Australia, most public meetings begin with an acknowledgement of Indigenous rights in the form of a 'Welcome to Country' ceremony. In this ceremony, a local Aboriginal elder (or Traditional Owner) or their representative is asked to officiate at the opening of the meeting and to welcome the visitors (i.e. any person that is not a local Indigenous person) to their land. This may be done with ceremonial activities such as didgeridoo playing, singing and dancing (corroboree), and sometimes with a smoking ceremony to expel the evil spirits. Protocol demands that the official visitors who speak after the initial welcome to country would each respond to the welcome by acknowledging Indigenous rights and sometimes past harm by saying words such as:

> *I begin by paying my respects to the traditional owners of this land on which we are meeting, both past and present, and especially to any elders present here today; by acknowledging the struggle that occurred for us to now share this land, by saying sorry for that struggle, and by appreciating the contribution that Aboriginal Australians can make to our society and culture.*

When circumstances are such that no Indigenous persons can be present to give the welcome, protocol requires that this acknowledgement be stated as a form of request to enter the country and thus is also a form of Welcome to Country. The exact wording used can vary depending on the purpose of the meeting, and it is considered polite to use the Aboriginal placename and/or the name of the tribal group in the statement of acknowledgement.

**For more information** on Indigenous peoples and FPIC, refer to:

African Commission on Human and Peoples' Rights, and the International Work Group for Indigenous Affairs 2006 *Indigenous Peoples in Africa: The Forgotten Peoples?* **http://www.achpr.org/files/special-mechanisms/indigenous-populations/achpr_wgip_report_summary_version_eng.pdf**

Buxton, A. & Wilson, E. 2013 *FPIC and the Extractive Industries: A Guide to applying the Spirit of Free, Prior and Informed Consent in Industrial Projects.* London: IIED. **http://pubs.iied.org/pdfs/16530IIED.pdf**

Charters, C. & Stavenhagen, R. 2009 *Making the Declaration Work: The United Nations Declaration on the Rights of Indigenous Peoples.* Copenhagen: International Work Group for Indigenous Affairs. **http://www.iwgia.org/iwgia_files_publications_files/making_the_declaration_work.pdf**

Convention on Biological Diversity 2004 *Akwe´: kon – Voluntary guidelines for the conduct of cultural, environmental and social impact assessment regarding developments proposed to take place on, or which are likely to impact on, sacred sites and on lands and waters traditionally occupied or used by Indigenous and local communities.* Montreal: Secretariat of the Convention on Biological Diversity. **https://www.cbd.int/doc/publications/akwe-brochure-en.pdf**

Doyle, C. & Whitmore, A. 2014 *Indigenous Peoples and the Extractive Sector: Towards a Rights-Respecting Engagement*. Baguio: Tebtebba, PIPLinks and Middlesex University. **http://www.piplinks.org/system/files/IPs-and-the-Extractive-Sector-Towards-a-Rights-Respecting-Engagement.pdf**

Hanna, P. & Vanclay, F. 2013 Human rights, Indigenous peoples and the concept of Free, Prior and Informed Consent. *Impact Assessment & Project Appraisal* 31(2), 146-157. **http://dx.doi.org/10.1080/14615517.2013.780373**

Hill, C., Lillywhite, S. & Simon, M. 2010 *Guide to Free Prior and Informed Consent,* Carlton: Oxfam Australia.

ICMM 2013 Position Statement, *Indigenous Peoples and Mining.* **http://www.icmm.com/document/5433**

ICMM 2010 *Good Practice Guide Indigenous Peoples and Mining.* **http://www.icmm.com/document/1221**

IFC 2012 *Guidance Note 7 Indigenous Peoples.* **http://www.ifc.org/wps/wcm/connect/50eed180498009f9a89bfa336b93d75f/Updated_GN7-2012 pdf?MOD=AJPERES**

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## Social Impact Assessment is not the same as Public Participation

Involving affected peoples and other stakeholders in the analysis of impacts and in the planning of mitigation and benefit strategies is essential. It is also highly desirable for the project to gain a social licence to operate. Traditional top-down approaches to decision making – often known as DAD ('decide, announce, defend') or even DEAD ('decide, educate, announce and defend') – are no longer acceptable in most societies and were seldom effective or sustainable. Instead, new participatory philosophies are heralded, sometimes called MUM ('meet, understand, modify') or POP ('public owns project'). In many jurisdictions, being able to participate is a legal entitlement, and there is a widely regarded 'right to participation' that is established in many international agreements (e.g. the 1998 Aarhus Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters). That "people have a right to be involved in the decision making about the planned interventions that will affect their lives" is a core value of the SIA profession as outlined in the *International Principles for Social Impact Assessment.*

SIA and public participation are not synonymous. SIA is a research and analytical process which intends to influence decision making and the management of the social issues. In order to do this effectively, it necessarily requires genuine community engagement – i.e. meaningful interaction and good faith dialogue, with interested parties having a real ability to influence the management of social issues. On the other hand, statutory public participation procedures are typically requirements to inform the public and allow them to have a say about a planned intervention. Unfortunately, in most mandated procedures, too often this say is disregarded by decision-makers, the process itself is seldom satisfying to most participants, and the so-called participatory process rarely does more than attempt to legitimate pre-determined outcomes or conform with regulatory requirements in a perfunctory, box-ticking manner. Such misappropriation of 'participation' is not only deceitful, it could have repercussions for current and future interventions as local peoples are likely to become disillusioned and cynical about the process and the project. In situations where it is perceived that decisions have already been made and the project is being pushed through, local people may consider that their participation is pointless and their energy will be better invested in protest actions against the project rather than in participating in a seemingly flawed and/or unjust assessment process. Therefore, project managers need to have a genuine commitment to meaningful engagement, not so much to meet any legal requirements, but to respect local communities and provide co-learning opportunities that arrive at useful outcomes and deliver shared value.

Effective participatory methods and participatory approaches provide many benefits, including:

(1) they provide a better understanding of the local values, knowledges and experiences of the different stakeholder groups;

(2) they provide an opportunity to validate data;

(3) they help the impacted communities understand the planned intervention and its implications, and thus assist them in planning for the change and to more easily adapt to and cope with the likely changes;

(4) they can help resolve conflicts over resource use;

(5) they help enhance the design of the project;

(6) they help win community support for project objectives and for implementation (i.e. a social licence to operate) thus avoiding protest action against the project.

The terms, public involvement, public participation, and community engagement, are essentially synonyms. Much more than simple consultation, informing the public, or extracting information from them, these concepts – public involvement, public participation and community engagement (hereafter collectively called 'community engagement') – refer to approaches that encompass a democratic philosophy about the rights of people in a community to be involved in decision making about matters that will likely affect their lives, as well as to a range of practices, methods and tools about how to effectively engage the public. There is also an underlying philosophy about empowerment and social inclusion, particularly of vulnerable and/or minority groups.

An important aspect of community engagement is the potential for deliberation and deliberative outcomes, and for collaborative learning and collaborative governance. Deliberation and deliberativeness are multidimensional concepts that can be defined as dialogue intended to induce deep reflection (i.e. serious consideration) of options and possibilities in an open and inclusive way (i.e. without the intrusion of power or politics), and that considers the concerns of all stakeholders. Deliberative methods are important because they enable people to think through the issues and thereby come to a more robust and potentially different conclusion than they would have otherwise.



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There are many reasons for using deliberative and empowering techniques, primarily that they lead to decisions that have greater legitimacy. However, there is also a downside: they can be more costly (at least in the short term) and more time consuming, and if not deemed necessary by the intended participants will be avoided by them. Respondent burden (the amount of ask of a community to participate) and respondent fatigue (when participants become over-consulted and lose interest) are issues that need to be recognised and managed. These issues are more likely to occur when people feel there is little value being accorded to their contribution, or when they feel there is little prospect their contributions will make a difference. It is therefore necessary to carefully design the engagement process to align with the expectations of stakeholders and with the significance of the issue. It will also be necessary to be flexible to cater for the changing interests of the various stakeholders. Interests and willingness to be engaged frequently vary over time depending on the way events unfold.

Participation and community engagement practices are frequently presented as a spectrum or continuum organized according to an increasing amount of public say and/or deliberativeness (see Box 6). Because of respondent burden and respondent fatigue, the idea is to use the techniques appropriate to the situation. The more intensive deliberation techniques are good to use when appropriate, but should not be used all the time. In cases where a project has a strong social licence to operate, informing and consulting techniques may be adequate in some situations.

## BOX 6: Example of a community engagement continuum

### IAP2's Public Participation Spectrum

The IAP2 Federation has developed the Spectrum to help groups define the public's role in any public participation process. The IAP2 Spectrum is quickly becoming an international standard.

iap2 international association for public participation

Increasing Impact in the Decision

| | Inform | Consult | Involve | Collaborate | Empower |
|---|---|---|---|---|---|
| **Public Participation Goal** | To provide the public with balance and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions. | To obtain public feedback on analysis alternatives and/or decisions. | To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered. | To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution. | To place final decision making in the hands of the public. |
| **Promise to the Public** | We will keep you informed. | We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision. We will seek your feedback on drafts and proposals. | We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision. | We will work together with you to formulate solutions and incorporate your advice and recommendations into the decisions to maximum extent possible. | We will implement what you decide. |



**Source:** International Association for Public Participation (**http://www.iap2.org**) (reproduced with permission)

It is sometimes argued that there should be payments made to participants (sitting fees) both to demonstrate that their contributions are valued, but also to ensure that a wider range of people can participate than would otherwise be the case. While sitting fees are sometimes a good idea, this can create perverse incentives. It is perhaps more important to ensure that people 'can hear that they have been heard' by having good feedback mechanisms that fully report and respectfully respond to the comments collected.

Encouraging people to participate can nevertheless be difficult. In many countries there is not a culture of participation, either because it is not part of the social culture, and sometimes because it has not been part of the political culture. In some regions which have had, or currently have, repressive regimes, promoting effective and meaningful participation may be particularly difficult. In these situations, no matter how good the intentions of the SIA practitioner, it may be hard to convince local people that there will not be ramifications to them as a result of the things they say about a proposed or actual project. This would be especially true if it was thought that the project was endorsed by the government, and/or if they thought that the SIA practitioner was a representative of the government.

Where serious divisions exist in a community, group-based processes may be required in the collection of information so that there is no suspicion that secrets were being told. In other situations, the unstructured interviewing of local residents may be best as a way of developing a full awareness of the experience of life in the community.

In some countries and for some planned interventions, difficulties relating to participation include the possible lack of familiarity affected peoples may have with the proposed activity. For example, what do high voltage transmission corridors mean to people who do not know what electricity is? What would a nuclear reactor mean? This is not an insurmountable difficulty, however, and there are ways of conveying some impression of the nature of the impacts that might be anticipated. However, it does imply that the participation process will take time, and may call for creative thinking. In all cases, it is essential to ensure that the form of participation used is relevant to local cultural values. Participation means more than soliciting the views of a few select people, and then ignoring them. In good SIA practice, participation means actively involving interested and affected peoples in decision-making processes that are meaningful to them.

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## Displacement and resettlement are a major cause of harm to impacted communities and a major risk to projects

Large projects typically displace people and disrupt their livelihoods. The large areas of land needed for the project site as well as for ancillary services – including land for worker accommodation, offices and for roads, pipelines, railway lines, electricity transmission corridors, water supply dams, etc – can lead to the need to resettle hundreds if not thousands of people. Being displaced and/or resettled can be a very traumatic experience for people, disrupting their sense of place, their livelihoods, their social networks and community connectedness. Resettlement is a major cause of human rights risks for companies. However, where projects are genuinely committed to a shared value proposition, the emotional distress from physical and economic displacement can be minimised and many livelihood benefits can be created when resettlement processes are effectively implemented.

Because displacement/resettlement is such a major social impact and human rights risk and is typically very costly for projects, it should be avoided wherever possible. Project alternatives that reduce the number of people who need to be resettled should be fully explored. Unfortunately, the costs and time taken to do resettlement are typically underestimated, leading to project delays and cost over-runs. Because resettlement is a major task in itself and such an impact, resettlement can be regarded as being a project within a project. Just like the project itself, the act of resettlement is a planned intervention that creates social impacts and therefore is a process that needs to be managed carefully and planned and conducted in a participatory way. Resettlement should be regarded both as an impoverishment risk, as well as an opportunity for development especially when all feasible opportunities for livelihoods enhancement and local content are fully explored.

Resettlement is the planned process of relocating people and communities from one location to another as part of the project-induced land acquisition necessary to allow a project to proceed. The resettlement process is intended to fully re-establish people in well-functioning communities and with appropriate sustainable livelihoods. There should be full and fair compensation for lost assets and any distress or inconvenience caused. Resettlement is regarded as being involuntary when the project site is fixed and the company has recourse to the power of eminent domain, and local communities have, in effect, no choice but to be resettled. Resettlement is regarded as voluntary when no state power of eminent domain is used, threatened, or perceived to be threatened, and local people do have a legal right to refuse to sell their land, but instead actively choose to be resettled in return for fair compensation and other livelihood benefits.

Physical displacement refers to the loss of housing resulting from project-related acquisition of land and/or restrictions on landuse that require the affected persons to move to another location. Economic displacement refers to situations where people's houses are not directly affected but where there is a loss of other assets or access to assets (e.g. agricultural land) that will result in a disruption of livelihoods and associated loss of income.

Any project that will cause physical or economic displacement must provide appropriate compensation, meaning that they must provide adequate solutions aimed at ensuring the improvement, or at least re-establishment, of living conditions and livelihoods. Where physical displacement occurs, there must be a formal resettlement process. With economic displacement, a formal resettlement process might not be necessary so long as there is a fair process of compensation and livelihood replacement and enhancement. In addition to the obligation to provide compensation and support for livelihood restoration and enhancement, projects are expected to provide benefits to affected communities. The social impacts on host communities (the communities which will host the people being resettled) also need to be considered, and there needs to be risk management and benefits to host communities as well as to the relocated peoples. Compensation should be understood not only cash compensation, but as the set of interventions, including social assistance, training, etc, which are aimed at ensuring that the project-affected person improves, or at least, restores his or her living conditions and livelihood.

Large projects, when approved by the national regulatory agencies, tend to be regarded as being in the national interest and the government's power of eminent domain (expropriation or compulsory acquisition) is frequently invoked or at least available to be used to bring the project to fruition. Consequently, most countries have national legislation regarding the use of expropriation and the entitlements of people who have to be resettled. In addition to these national requirements, there are international standards that should also be met, and may be required if there is funding from the World Bank, the IFC, or another MDB or aid agency, or an Equator Principles financial institution. Complying with these international standards and doing resettlement effectively may well reduce overall costs and risks to the project. They include:

- World Bank: OP 4.12 Involuntary Resettlement, **http://go.worldbank.org/96LQB2JT50**
- IFC: Performance Standard 5 Land Acquisition and Involuntary Resettlement, **http://www.ifc.org/wps/wcm/connect/3d82c70049a79073b82cfaa8c6a8312a/PS5_English_2012.pdf?MOD=AJPERES**



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- Equator Principles: **http://www.equator-principles.com/** (in effect, the Equator Principles require observance of IFC PS5).
- Other multilateral or bilateral development banks and bilateral aid agencies may have their own requirements.

These international standards tend to have similar procedures and expectations. Very early in the life of a project, a **Resettlement Policy Framework** (RPF) should be developed that outlines the project's policy and general procedures about how land acquisition, resettlement, compensation and livelihood restoration and enhancement will be undertaken. This needs to be done early so that no false promises are made or implied to people in the early stages of the project, such as in land surveying or geological exploration, or even by the SIA consultants. Later, a **Resettlement Action Plan** (RAP) needs to be developed that fully details the operational process of enacting the resettlement. To avoid speculative or opportunistic behaviour by local people and to manage in-migration, an inventory of houses, other buildings and all assets should be undertaken as soon as practical. There should be a firm **Cut-off Date** after which no additional structures or other assets become eligible for compensation. By having good communication with affected communities and a fair resettlement and compensation process, there will likely be widespread approval of the cut-off deadline. Because resettlement is a project within a project, there needs to be a high level of coordination between resettlement activities and the rest of the project. Activities in the resettlement process need to cross-link with the project-level Social Impact Management Plan and other project plans such as the Community Health & Safety Plan, the Community Development Plan, the Stakeholder Engagement Plan, the Local Employment and Procurement Plan, and any Health Plan. In a large-scale resettlement, potentially there might be separate plans for the resettlement process as distinct from the project as a whole. In any event, a **Livelihood Restoration & Enhancement Plan** (LRP or LREP) will be required, usually as part of the RAP. The resettlement process should not be considered to be complete until all adverse impacts of resettlement have been addressed. A Completion Audit should be undertaken by an independent external party to assess whether all impacts have been addressed, how the standard of living of resettled individuals compares to their previous situation, whether they have remaining grievances, whether international standards and national legislation has been observed, and whether all provisions within the RAP and LRP have been met. The **Completion Audit** should only be undertaken once all mitigation measures have been substantially completed and once displaced persons are deemed to have been provided adequate opportunity and assistance to sustainably restore their livelihoods. This will necessarily be several years after being resettled, and not straight after the relocation. For resettlement to be sustainable, the company must be able to responsibly exit at some point in time. It is very important, therefore, to plan for exit during the development of the RAP in the same way that preparation for closure is done at the commencement of the project. The **Exit Plan** should be agreed with the community and approved by the regulatory authority. In addition, the capacity (in human and financial terms) of local governments to take over the management of resettlement towns is critical to the long-term improvement of livelihoods. Building this capacity within government should therefore be part of exit planning.

In general terms, the international standards expect that, wherever possible, each project will:

- avoid or minimise displacement by exploring alternative project designs;
- avoid forced eviction by using negotiated agreements;
- anticipate and minimize adverse social, economic and human rights impacts;
- provide appropriate disclosure of information, and allow for the informed participation of those affected (arguably to the level expected by free, prior and informed consent);
- ensure that women's perspectives are obtained and that their interests are factored into all aspects of resettlement planning and implementation;
- apply compensation procedures in a transparent and consistent way to all communities and persons;
- provide compensation for loss of assets at replacement cost;
- avoid paying compensation in cash, at least to vulnerable people, i.e. pay compensation in kind to avoid that the compensation will be squandered;
- observe the principle of 'land for land' – where the livelihoods of displaced persons are land-based or where land is collectively owned, the project is to provide compensation in the form of replacement land;
- improve the livelihoods and standards of living of displaced persons;
- identify individuals and groups who might be disproportionately impacted due to their disadvantaged or vulnerable status, and put measures in place to ensure they have access to development benefits and opportunities;
- improve the living conditions of physically displaced persons by providing adequate and improved housing with security of tenure at resettlement sites;



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- provide a choice of options to affected individuals and consult with communities over community assets and resources;
- provide opportunities to displaced communities and persons to derive development benefits from the project;
- provide transitional support for a reasonable period of the time to enable people to restore their income-earning capacity, production levels, and standards of living;
- take every effort to ensure that people will not be double-resettled;
- establish effective grievance mechanisms as early as possible in the project development;
- establish procedures to monitor and evaluate the implementation of a Resettlement Action Plan and Livelihood Restoration Plan and take corrective action as necessary.

One of the most controversial and complex aspects of resettlement relates to compensation. Where people are physically displaced, project proponents are required to resettle them by providing replacement housing and assist them in restoring and enhancing their livelihoods. Where people are economically displaced, they are entitled to compensation for lost assets and to assistance to restore and enhance their livelihoods. A requirement of the international standards is that compensation should be calculated on the replacement value of any assets lost. Such determination should factor in any likely inflation that will occur between the time at which the assessment is made and when compensation is actually paid. Where the value of the lost assets exceeds amounts that would normally be managed by people, compensation should be paid in kind rather than in cash. Paying out large amounts of cash can increase the harm from a project. It will immediately lead to local inflation. It will likely lead to unwise or inappropriate spending on consumer goods rather than being invested in restoring or enhancing sustainable livelihoods. Past experience has time and again revealed that cash compensation is a major cause of impoverishment. Part of livelihood restoration and enhancement should involve capacity building, which perhaps should include training in managing finances. Finding opportunities for how individuals to be resettled might be involved in the resettlement process should be explored.

With millions of people being resettled every year, there is much experience of the consequences of resettlement. Unfortunately, the practice of conducting resettlement is still poorly done and there is much that can be improved. There are several key lessons. First, as resettlement has largely been forced on people and is something done to them, finding opportunities to empower people in the process, giving them choices and autonomy, is important. Second, the actual experience of resettlement tends to be traumatic for the people being resettled, and therefore it is important that resettlement practitioners give attention to the emotional and health needs of people to be resettled. Thinking through and discussing the process with the affected peoples may identify many ways in which the process can lead to a strengthening of the community. For example, certain key people might be resettled first and then they can act as a welcoming committee for the people being resettled. Creating ceremonies for saying goodbye to the old settlement and celebrations for the new settlement are important. Allowing people to have nostalgia about the old, but also to have excitement, anticipation and adventure about the new is necessary. Being receptive to concerns and responding quickly to them is important in ensuring that there is a positive attitude rather than an aggrieved mentality that might otherwise develop. Some other key lessons are:

1. The cost of resettlement and the time taken are always under-estimated.
2. Starting early is essential, and the resettlement planning needs to be built into the project planning process.
3. There should be planning for project expansion. People should not be resettled into places where they will later need to be resettled again. Land needed for future expansion should be protected from in-migration.
4. The time between the development and approval of the RAP and its implementation should be minimised. The wider this time period is, the more difficult the implementation becomes.
5. The specifics of the location of the resettlement site are critical in achieving a successful resettlement outcome, especially livelihood restoration and enhancement. Resettlement site selection should be driven by a range of criteria including distance from origin and compatibility of the characteristics of the site (e.g. land quality, water supply, agricultural productivity) with the livelihoods of the people to be resettled.
6. Resettlement is an expensive process, however the overall, long-term cost to the project will be much less when it is done properly. Furthermore, the costs of getting it wrong far exceed the costs of doing it right.
7. Expropriation must only be a last resort. Expropriation takes much longer than is usually considered, it attracts negative attention from interested stakeholders, and it can create opposition to the project. It will never lead to a social licence to operate. Negotiating with people in such a way that they voluntarily participate in a resettlement process is much more likely to be effective than relying on the power of eminent domain.

8. Involve resettled people in the design of replacement accommodation.
9. Be careful that unrealistic expectations are not created during consultation meetings, or by project staff in early project activities. All promises or offers should be recorded in a Commitments Register.
10. Professional planning and proper community negotiation are keys to success. Taking shortcuts will only lead to problems later on.

Michael Cernea identified eight major impoverishment risks to people that commonly arise from project-induced displacement and resettlement: landlessness; joblessness; homelessness; marginalisation; increased morbidity and mortality; food insecurity; loss of access to common property; and social disarticulation. Thinking about these risks and enacting strategies to counter them are key to successful resettlement and successful projects that deliver shared value. Resettlement processes and activities that provide land-based resettlement, identify employment and other alternative livelihood opportunities, construct houses for people to live in and implement processes for people to become reconnected as communities, consider inclusivity and options for people to be engaged, provide primary health care and preventative care, ensure adequate nutrition and food and water security, minimise loss of access to or restore or replace community assets, and build social and community capital, are likely to lead to effective resettlement.

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Satiroglu, I. & Choi, N. (eds) 2015 *Development-Induced Displacement and Resettlement*. London: Routledge. **http://www.routledge.com/books/details/9781138794153/**

Scudder, T. 2005 *The Future of Large Dams.* London: Earthscan.

Vandergeest, P., Idahosa, P. & Bose, P. (eds) 2007 *Development's Displacements: Economies, Ecologies and Cultures at Risk.* Vancouver: UBC Press.

World Bank 2004 *Involuntary Resettlement Sourcebook: Planning and Implementation in Development Projects*. Washington, DC: World Bank. **http://hdl.handle.net/10986/14914**



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## Local Content helps create shared value

In its simplest formulation, local content refers to the requirement, expectation or commitment of a company to ensure that value is retained within a host country, region or community through its workforce and/or procurement opportunities. More than this, however, local content is a philosophy about shared value that considers the strategies a business can enact to increase local content to maximise benefits to the local community and company alike. For example, a company can work with its potential local suppliers to consider how their capacity can be built to meet its procurement requirements and/or how company requirements might be able to be adjusted so that local businesses are not artificially excluded from consideration. Some governments mandate a certain level of local content. While there is much variation in definitions of 'local' and 'content' across countries, and even within the same country, the SIA practitioner needs to be aware of the policies, regulations, contractual stipulations and stakeholder expectations as they relate to the project. Local content presents one of the best opportunities for companies to achieve social license. For many projects, however, training local people for employment with the project and supporting local businesses to supply the project is not done early or effectively, and thus a development opportunity is missed.

The growth in local content policies and practice has brought to light competing objectives and other challenges for private sector proponents and governments, who are faced with designing local content in a way that contributes to sustainable regional development, enhanced wellbeing and quality of life for local communities, as well as national development priorities and industrial policies. Governments seek to achieve a range of objectives with these policies, such as employment creation, development of specific sectors or industries, capacity building, knowledge generation, skills and technology transfer, and addressing trade imbalances. Corporate attitudes towards local content have evolved in recent years. In many instances, the initial motivation was a need to comply with formalised commitments, either to a host government, an investment partner, or an Indigenous community. Compliance was deemed necessary in order to secure access to resources. Over time, however, leading practice companies had become increasingly motivated by the desire to establish and maintain enduring partnerships with local stakeholders for mutual benefit and shared value. They have also realised the value of reducing their dependency on expensive expat workforces.

SIA can be a valuable tool to inform strategies that approach local content from a regional development perspective, based on an assumption that it is possible for resource developers and local governments to design collaborative local content strategies so as ensure foreign companies contribute to regional development by sourcing from local businesses and recruiting local people. Acting through the regional multiplier effect, local content can stimulate economic activity and encourage additional investment and higher employment in the local economy. A more prosperous local economy will also attract new suppliers to the area and lead to a more competitive supply base as well as reduce the community's dependence on any one industry.

An important step is to start off with a basic socio-economic analysis to determine the baseline conditions in the host economy: the existing level of economic dependency on the sector; the specific industries that should be encouraged to operate in the region due to their linkages and multiplier effects; and the presence or absence of enabling conditions for local content development related to the project. This analysis draws on a variety of indicators such as ease of doing business, service amenities, local infrastructure, the health of local businesses, and the diversity and adaptability of local communities to lead their own capacity-building efforts.

An important indicator of the health of the local economy is the level of economic dependency on one or several sectors in the region. The market share of the industry can be estimated by using the concentration of employment in a given industry in the area. Economic diversification, which can be achieved through project enhancement/ social investment programs, can be a solution to the problem of dependency in one or several industries. The goal of sustainable regional development, however, requires consideration of a broader set of issues beyond the traditional indicators of economic health. It is also important to consider other factors contributing to the strength of human capital, economic capital and institutional capital.

Potential suppliers can be identified through a comprehensive supplier capability study. This involves a number of activities: (i) engaging the individuals who manage the contracts to get an in-depth understanding of the current providers of goods and services, the contracting strategy, end-user requirements and 'suitability' for local content based on various criteria; (ii) identifying/mapping the businesses across the full spectrum of sectors present in the operator's supply chain; (iii) a high level analysis of sectors, based on their attractiveness for local content; (iv) prioritising; (iv) an in-depth analysis of the value chain in shortlisted sectors and of the capability/capacity gaps of potential suppliers; (v) developing a competitiveness strategy for targeted sectors; (vi) designing an implementation plan; and (vii) monitoring progress.

Developing a local workforce requires starting with a demand analysis of direct and indirect labour by project phase. A second step involves mapping the existing workforce skills against demand. An important input into the demand vs supply gap analysis is an analysis of the quality gaps in academic institutions and training centres, particularly in engineering, technical and vocational education. Such an analysis may involve assessing infrastructure, equipment, curricula, teaching, and capacity. The final step involves the design and implementation of training interventions, typically using a partnership approach. In this way, a project can build the workforce it needs locally.

Local content strategies, like other project interventions, should be assessed for potential adverse social impacts. For instance, at a local level, the resources may be drawn (poached) from other businesses and services in the area leading to reduced capacity in those sectors (for example from government and other fixed income earners). Local businesses can become vulnerable to the project's cycles by becoming dependent on them. Another potential issue is awarding only small value contracts to local people, which may trigger community dissatisfaction because they expected more. The preferential contracting/recruiting of particular groups (which can happen inadvertently if inadequate social profiling is done) could negatively affect social cohesion and reinforce 'elite capture'. These issues should be systematically considered as part of the baseline analysis, as well as in the risk assessment prior to implementing local workforce or local supplier development programs.

**For more information** on local content and local procurement, refer to:


Esteves, A.M. & Barclay, M.A. 2011 Enhancing the benefits of local content: Integrating social and economic impact assessment into procurement strategies. *Impact Assessment & Project Appraisal* 29(3), 205-215.
**http://dx.doi.org/10.3152/146155111X12959673796128**

Esteves, A.M., Brereton, D., Samson, D. & Barclay, M.A. 2010 *Procuring from SMEs in Local Communities: A Good Practice Guide for the Australian Mining, Oil and Gas Sectors.* Brisbane: Centre for Social Responsibility in Mining, Sustainable Minerals Institute, University of Queensland.
**http://www.csrm.uq.edu.au/docs/4361%20CSRM%20SME%20Report%20Email%20V2.pdf**

Esteves, A.M. & Ivanova, G. 2015 "Using Social and Economic Impact Assessment to guide local supplier development initiatives", in Karlsson, C., Andersson, M. & Norman, T. (eds) *Handbook of Research Methods and Applications in Economic Geography.* Cheltenham: Edward Elgar, pp.571-596.
**http://www.e-elgar.com/bookentry_main.lasso?currency=US&id=14395**

Hidalgo, C. et al. 2014 *Extracting with Purpose.* FSG.
**http://www.fsg.org/tabid/191/ArticleId/1184/Default.aspx?srpush=true**

IFC (in collaboration with Engineers Against Poverty) 2011 *A Guide to getting started in Local Procurement: For companies seeking the benefits of linkages with local SMEs.* **http://www.ifc.org/wps/wcm/connect/03e40880488553ccb09cf26a6515bb18/IFC_LPPGuide_PDF20110708.pdf?MOD=AJPERES**

Tordo, S. et al. 2010 *Local Content Policies in the Oil and Gas Sector.* Washington: World Bank.
**http://documents.worldbank.org/curated/en/2013/01/17997330/local-content-oil-gas-sector**




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## Plan for closure at commencement of the project

Projects are, by definition, only for a fixed term. Some projects have a designated life of many decades, others have a relatively short life expectancy of a few years or even less. For some projects, closure is a planned event that occurs when originally intended as per the original plan and licensing approval. However in some sectors, notably the extractive industries, the volatility of commodity prices means that projects can have an uncertain lifespan and may unexpectedly go from full production and a long-term horizon to reduced operations, temporary closure ('put on ice'), or permanent closure within a short timeframe. The lack of a social licence to operate can also lead to protest and other actions that may bring about the premature closure of a project. To some extent, projects that have a large construction workforce but a small operations workforce (e.g. a dam) need to manage the shift from construction to operation (i.e. workforce demobilisation) in a somewhat similar way to a closure process, at least from a social perspective. It is therefore being increasingly realised that all projects need to plan for closure early in the life of the project and to update their closure plans regularly, especially if there are major changes to the project or its operating environment. Closure planning is necessary for new projects and also for existing projects that have not yet considered their closure planning strategy. Even where there is a closure plan, having a dedicated SIA for closure would be appropriate.

Closure can have major social impacts especially when communities are economically dependent on the project. However, project closure can also have indirect social impacts when environmental impacts are not properly addressed and rehabilitation not properly done. For example, acid mine drainage and other forms of environmental pollution can continue long after actual operations have ceased, and can significantly affect the livelihoods and health of people living in the vicinity of mines.

A closure strategy should exist from commencement of the project. Closure is not a simple act, but is a process comprising several phases including closure planning, decommissioning, cessation, and post-closure. Decommissioning involves a number of activities undertaken to prepare for cessation of operations and the consideration of different options for the post-closure period. Decommissioning should normally commence well before the end of operations (i.e. cessation) so that the preferred options can be adequately considered and negotiated with stakeholders before they need to be implemented. Post-closure is the phase after cessation which comprises the ongoing remaining activities of monitoring and maintenance to ensure that all ongoing environmental, health and safety risks are controlled and minimized, and that all promised social benefits were delivered.

Closure planning must be a process negotiated with local communities and other stakeholders. Many key decisions will have ongoing long-term effects on surrounding communities and therefore these communities need to be involved in decisions around closure planning. First and foremost is the impact of job loss. Much can be done in identifying economic opportunities post-closure and in providing retraining. The future use of the site is usually a key concern for surrounding communities. Identifying potential future uses by the community of project buildings and other infrastructure, and the site itself, can enhance the benefits of the overall project to the community. Electricity generation and water treatment plants and other infrastructure may be able to be made available to the local government or other operator on behalf of the local communities (although this also entails a transfer of liability that also needs to be considered). The ongoing life of the company's social investment activities and any corporate philanthropic actions need to be considered.

To ensure an ongoing social licence to operate and good reputation, it is in the company's interest to have a high level of transparency and engagement with the local communities. Local people will be potentially greatly affected and they also need to make their own plans. Their intentions for the post-closure period need to be thought through, and their decisions may change as they process the information available to them and consider their options. They need to consider whether they should stay, go, sell, buy, etc. When people's intentions are known, the potential impacts of closure can be determined. It is also possible to align closure actions with people's preferences.

The closure process cannot be finalised until all of the following issues have been addressed:

1. all resettlement processes and associated livelihood restoration and enhancement activities have been completed and/or a realistic plan has been made for their continued operation;
2. all compensation that is due has been provided;
3. all items in the Commitments Register and all items in any Impacts & Benefits Agreement (or similar community development agreement) have been delivered or addressed;
4. all grievances that have been submitted have been addressed;
5. a plan for all facilities and infrastructure has been made in consultation with all stakeholders, and each item will either be re-utilised by the local community or has been removed;
6. all appropriate steps have been taken to ensure the area is safe and stable, for example capping all shafts, and removing all chemicals;
7. all site rehabilitation (restoration or remediation) works have been undertaken consistent with regulatory requirement and any commitments made;



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8. all social and environmental mitigation activities have been fully implemented and, where they continue to be necessary, there is an appropriate mechanism for their continuation;
9. there is a process for the ongoing monitoring of key environmental and social indicators and an adaptive responsive procedure should there be an exceedance;
10. there is a sustainable management strategy for all social investment programs; and,
11. there is a contingency fund or mechanism to address any unexpected issues related to the project that may emerge in the future.

It is important for companies to be aware that their project approval (environmental licensing consent) and acceptance by the local community was on the basis that there would be no residual harm and that certain benefits would be provided. The company has an obligation to abide by those undertakings irrespective of any changed circumstances it might experience.

Closure is an expensive process. A challenge is the fact that most expenses related to closure are incurred after production (and therefore income generation) ends. Therefore financial provision for closure must be made by the company during the operational phase of the project. This requires careful estimation of the likely costs of closure and the creation of a reserve fund so that the money needed for closure will exist when it is needed. Unfortunately, the estimation of the costs of closure is usually poorly done, and many companies fail to fulfil their obligations when it comes to closure. For this reason, many countries impose an environmental bond at project approval stage to ensure that there are funds to cover expenses related to closure. Unfortunately, these environmental bonds are typically only for a fraction of the true costs of rehabilitation, and they fail to keep pace with inflation. Because of this, an improved system of providing surety to cover the costs of closure is needed. A closure audit is needed to determine whether the closure process has been properly conducted, and that all the issues/conditions mentioned above have been fulfilled. Only then should any environmental bond be released.

To ensure that a positive legacy eventuates, a project should contribute to sustainable development in such a way that the local communities will continue to develop after the project ends. To this end, the strategic long-term corporate goals should be aligned with current and future development plans of the community and the region. The company should engage stakeholders and pursue initiatives aimed at strengthening the capacity of the local community. Ideally, these principles should be in place from the early stages of a project, be present in the strategic social investments and local content strategies of the project, and they should be carefully considered during the decommissioning stage. The ongoing social licence to operate and grow (i.e. operate at other sites) of a company depends on how effectively it undertakes its closure processes.

**For more information** on closure, refer to the following (but note that in most of these guidelines on closure there is still a lack of consideration of social issues):

Anglo American 2013 Mine Closure Toolbox **http://www.angloamerican.com/~/media/Files/A/Anglo-American-PLC-V2/documents/approach-and-policies/environment/toolbox-main-brochure-lr.PDF**

Australian Government 2006 *Mine Closure and Completion.* Canberra: Department of Industry, Tourism and Resources **http://www.industry.gov.au/resource/Documents/LPSDP/LPSDP-MineClosureCompletionHandbook.pdf**

Evans, R. 2011 "Closure planning", in Vanclay, F. & Esteves, A.M. (eds) *New Directions in Social Impact Assessment: Conceptual and Methodological Advances*, Cheltenham: Edward Elgar, 221-232.

Sánchez, L.E., Silva-Sánchez, S.S. & Neri, A.C. 2014 *Guide for Mine Closure Planning.* Brasília: IBRAM (Brazilian Mining Association). **http://www.ibram.org.br/sites/1300/1382/00004552.pdf**

Sheldon, C.G., Strongman, J.E. & Weber-Fahr, M. 2002 *It's Not Over When It's Over: Mine Closure around the World,* Washington: World Bank and International Finance Corporation.
**http://siteresources.worldbank.org/INTOGMC/Resources/notoverwhenover.pdf**

Stacey, J. et al. 2010 *The Socio Economic Aspects of Mine Closure and Sustainable Development* (2 volumes). Johannesburg: Centre for Sustainability in Mining and Industry, University of Witwatersrand.
Vol 1: **http://www.coaltech.co.za/chamber%20databases%5Ccoaltech%5CCom_DocMan.nsf/0/13C0E50053B60B8788257AF4003392EC/$File/Coaltech%20Mine%20Closure%20Report%201%202010.pdf**
Vol 2: **http://www.coaltech.co.za/chamber%20Databases%5Ccoaltech%5CCom_DocMan.nsf/0/F6430BA4F25ADE3A88257AF4003321AA/$File/Coaltech%20Mine%20Closure%20Report%202%202010.pdf**

World Bank 2010 *Towards Sustainable Decommissioning and Closure of Oil Fields and Mines: A Toolkit to Assist Government Agencies* (version 3.0). Washington: World Bank.
**http://siteresources.worldbank.org/EXTOGMC/Resources/336929-1258667423902/decommission_toolkit3_full.pdf**



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# Ethics for SIA practitioners

Ethical issues and dilemmas arise in all professional practice. A hallmark of professionalism is an ongoing discussion of ethical issues and an active, reflexive awareness by practitioners and the profession as a whole of the ethical issues likely to be encountered. Vanclay et al. (2013, modified) identified 18 general principles relating to ethical research involving humans that arguably should also be observed by SIA practitioners. These principles are:

1. Respect for participants – An SIA practitioner should demonstrate respect in terms of all their interactions with participants including not judging them, not discrediting them, in ensuring that their views are faithfully recorded and given due consideration in the assessment process. Part of this respect is implied by the terminology of 'participant' (rather than 'respondent' or 'subject'). An important dimension of this respect relates to ensuring the protection of persons with diminished autonomy and those who are marginalised or vulnerable. Special recognition and procedures may also be required in the case of Indigenous peoples.
2. Informed consent – Participation should be the voluntary choice of the participants and should be based on sufficient information and an adequate understanding of the SIA research and the consequences of their participation. This implies that the practitioner must disclose all relevant information and any possible risks of participation, especially any issues around what will happen to the data obtained. Where culturally appropriate, informed consent could be documented by having signed consent forms.
3. Specific permission required for recording – If the practitioner intends to audio-record, video-record or photograph any participant, specific approval for this must be given in advance (and may be a legal requirement under the privacy legislation of most countries).
4. Voluntary participation and no coercion – As implied by the principle of informed consent, participation must be voluntary and not subject to any coercion or threat of harm for non-participation. Non-coercion is not taken to mean that there should not be payments for participation, however, any such payment should be commensurate with the amount of time and normal income expectations of the participants, and should not be excessive such that it would constitute a bribe or inappropriate inducement.
5. Right to withdraw – Consistent with the principle of voluntary participation, participants must know that they can withdraw at any time and have any of their data already recorded removed from the analysis where this is possible.
6. Full disclosure of funding sources – An implication of the principle of informed consent is that there must be full disclosure of the sources of funding of the research.
7. No harm to participants – It is fundamental that no harm must foreseeably come to participants as a result of their participation in the research. This means not only that participants must not be exposed to pain or danger in the course of the research (such as in medical research), but also that there must be no adverse consequences to a person as a result of their participation. At the very least, the practitioner must do their utmost to protect participants from any harm, and ensure under the principle of informed consent that the participant is fully appraised of all possible risks of participation. Sometimes, participation in social research will cause a participant to reflect on personal issues bringing about emotional distress. Here the practitioner's obligation is to ensure that the immediate interaction does not finish until there is some resolution to the distress that has arisen and that access to follow-up assistance or counselling is available if needed.
8. Avoidance of undue intrusion – Respect for participants means that there will be discussion only of those matters that are relevant to the issues under research and that enquiries should be confined to those issues. It implies a respect for the personal lives of participants and that practitioners should be cognizant of what is personal and private.
9. No use of deception – The principle of respect for participants and professional integrity implies that the use of deception or covert methods should only be used under certain circumstances and only when approved by a duly-appointed ethics committee.
10. Presumption and preservation of anonymity – There is an assumption of anonymity, that is, people participate in research on the presumption that they will be anonymous and that their anonymity will be protected, unless they have given permission to be named. Thus, there is a requirement for the express permission of participants for any use of the real names of people or where a person' identity would be evident from the context (for example, the mayor or other public figure identified by the public role).
11. Right to check and modify a transcript – Where people are named or identifiable, those participants have the right to check how they are quoted and to make changes to a transcript and any draft publication that may be prepared to ensure they agree with the way they are recorded. Best practice in social research would accord this right to all participants.



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12. Confidentiality of personal matters – Respect for participants means that confidentiality (i.e. non-disclosure of information) should be accorded to all private or personal matters or views, or when any such undertaking is given. This means that there is a responsibility on the practitioner to make judgements about what should be reported and what should not be publicly disclosed. The fact that something was revealed to the practitioner does not automatically entitle the practitioner to make it public. When information is entrusted to a practitioner in confidence, such confidentiality must be protected.
13. Data protection – Because of the confidentiality of personal data and the identities of who was included in the research, care must be taken to ensure that all data are stored securely and safe from unauthorised access. It is also expected that there be a stated timeline after which the data would be destroyed. Because of institutional requirements that practitioners should be able to produce raw data in the event of an audit or complaint and to safeguard against fraud, typically this would be a number of years after completion of the project.
14. Enabling participation – Practitioners have an ethical responsibility to ensure that all relevant individuals and groups are included in the research, and where they might ordinarily be excluded – e.g. by reasons of language, gender inequalities, cultural protocols, physical accessibility, cost to participate, or other factors contributing to social exclusion in the particular project context – there must be a genuine attempt to enable participation by providing appropriate means of access such as translation, transportation, or payments to offset the cost of attendance.
15. Ethical governance – For the proper functioning of ethical procedures, it is necessary that there be an ethical governance mechanism. Typically this implies that there should be a committee or other facility that can – especially in the case of ethically-sensitive research issues or methods (such as use of deception, interviewing of vulnerable groups) – review research protocols prior to the research taking place, oversee and/or monitor research activities, provide advice to practitioners and participants, and make judgements in relation to complaints. A professional association such as IAIA may be able to provide such a mechanism, alternatively this could be negotiated in conjunction with the impacted community or with a local authority (local, regional or national government), or a local university, etc.
16. Grievance procedure – Good ethical governance requires that research participants have access to a grievance procedure and recourse to corrective action in relation to their concerns about the way the SIA research was conducted. The grievance procedure must be procedurally fair, and disclosed to participants.
17. Appropriateness of research methodology – Respect for participants as well as professional probity means that the research procedure must have reliability and validity. Participants give their time (whether free or paid) on the presumption that the research is legitimate, worthwhile and valid.
18. Full reporting of methods – Research methods and analytical procedures must be fully disclosed to: enable replication of the research by another practitioner; enable peer review of the adequacy and ethicality of the methodology; and to encourage critical self-reflection on the limitations of the methodology and any implications for the results and conclusions.

**For more information** on research ethics, refer to:


Israel, M. & Hay, I. 2006. *Research Ethics for Social Scientists: Between Ethical Conduct and Regulatory Compliance*. London: Sage.

Vanclay, F., Baines, J. & Taylor, C.N. 2013 Principles for ethical research involving humans: Ethical professional practice in impact assessment Part I. *Impact Assessment & Project Appraisal* 31(4), 243-253.
**http://dx.doi.org/10.1080/14615517.2013.850307**

Baines, J., Taylor, C.N. & Vanclay, F. 2013 Social impact assessment and ethical social research principles: Ethical professional practice in impact assessment Part II. *Impact Assessment & Project Appraisal* 31(4), 254-260.
**http://dx.doi.org/10.1080/14615517.2013.850306**




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## Good practice guidance for the 26 tasks comprising SIA

Box 2 near the beginning of this document presented the 26 tasks that comprise SIA. Here, each of those tasks is considered in turn with comments made about the key issues that deserve specific attention in terms of establishing good and sometimes best practice. This is not a how-to-do-it instruction manual. Not all the information here will necessarily be applicable in every situation – people utilising this information will need to establish for themselves what is appropriate in each particular context. It is also important to realise that while the tasks are presented in roughly chronological order, they frequently overlap in timing, and they inform each other. Sometimes the outcomes from a later step provide information that can lead to a need to revisit information and/or decisions arising from an earlier step.

## Phase 1: Understand The Issues

### **Task 1:** Gain a good understanding of the proposed project, including all ancillary activities necessary to support the project's development and operation.

To understand the social impacts of a project, it is vitally important to understand the project and all its various dimensions. Projects generally involve multiple ancillary activities and different components. Impacts are usually created by each of the component activities of the project as well as along the whole value chain. Thus, a thorough impact assessment needs to consider all of the impacts created by each of the activities that make up the overall project. For example, a project may entail the resettlement of people, which will also have impacts in the locality where they are resettled. Worker accommodation complexes have impacts on local communities. Dams may require quarrying activities at sites distant to the proposed dam, with the transportation of rockfill to the dam site.
All projects require the transport of goods in and out of the project site. These transport routes are also sources of negative (and potentially positive) impacts. To fully understand a project and the context in which it is in, a scoping visit to the project site is necessary – this is not something that can be done as a desktop planning exercise.

### **Task 2:** Clarify the responsibilities and roles of all involved in or associated with the SIA, including relationships to the other specialist studies being undertaken, and establish what national laws and/or international guidelines and standards are to be observed.

Environmental impacts invariably lead to social impacts, and health impacts and human rights impacts can also be understood as social impacts. Therefore, having a good understanding of the other studies being conducted and ensuring integration and complementarity with them is necessary to ensure efficiency, effectiveness and to reduce the burden on local communities. A key step, therefore, is coming to agreement on the scope of the SIA to be conducted. It is worth noting that, like all professional practitioners, an SIA practitioner has a duty of care to ensure certain things are considered by the client. In the case of SIA, this would include ensuring that a wide range of issues were considered by the project, either in the SIA or in other studies. Furthermore, since SIA is necessarily an iterative learning and participatory process, it is impossible to determine at the outset everything that will need to be considered. Therefore, those commissioning and conducting SIAs should allow flexibility in contracting budgets in order that the SIA can respond to new issues that may arise and need to be assessed. It is self-evident that the budget must be adequate for the task of assessing all the relevant issues. Also important, however, is that the time schedule for the SIA should ideally correspond to the proponent's development plans to maximise the ability of the SIA to feed into the planning process without causing delays. Awareness of this and planning for this is a joint responsibility of the proponent and the SIA consultant.

Large projects always occur in a multi-governance setting. The various layers of governance that potentially can have bearing on a project and therefore on SIA activities include the content of international agreements (such as the United Nations *Guiding Principles on Business and Human Rights*), international norms (such as might be specified in industry association guidelines), matters prescribed in the national constitution, the national policy environment, national legislation and regulation and the way it is enacted, environmental licensing and permitting conditions, and matters stipulated in any other contractual agreements between government and the proponent. Where the proponent has a contractual Impacts & Benefits Agreement or similar with the local community, this too will impose specific conditions that need to be considered. Sometimes, especially in countries that are federations, there may be differences between national, state or province, and local or municipal government requirements and expectations. In addition to this, large projects are frequently undertaken by consortia involving several corporations, each with their own policies and procedures. Finally, large projects may have financial backing from many sources. Unfortunately, while the approaches of the various multilateral development banks (e.g. World Bank, IFC, ADB, AfDB, EBRD, EIB, IDB, etc) are similar, they are not identical, and each often requires their own procedures to be followed and documentation to be produced.

Even where there is no MDB financing, commercial financial institutions around the world are increasingly signing up to the Equator Principles and observance of the Equator Principles may be a requirement of project financing. For operational guidance, the Equator Principles require compliance with the IFC's Performance Standards making them something of an international standard whether or not IFC funding is part of the project. Many companies set the IFC Performance Standards as their practice benchmarks. It is therefore important that all SIA practitioners are aware of the IFC Performance Standards.

This multi-governance setting creates many issues for projects. While there are sometimes contradictory guidelines, there may also issues where there is a lack of guidance. It may be desirable for the SIA practitioner to develop a gap analysis to consider the differences between national and international standards. It will also be important for the SIA practitioner to negotiate with their client (typically the proponent) about which standards are to be observed. Where there are conflicts between national regulation and international standards, these will need to be spelled out and negotiated. Ensuring that all parties understand the ramifications of any non-compliance will also be important.

### **Task 3:** Identify the preliminary 'social area of influence' of the project, likely impacted and beneficiary communities (nearby and distant), and stakeholders.

The concept of a primary area of influence or zone of impact is standard in EIA practice, however, it is not directly transferable to SIA. A 'social area of influence' consists of the people potentially impacted by a project. Affected peoples include both 'communities of place' and 'communities of interest'. The location of affected people frequently does not neatly align with the geographic boundaries or the area of influence determined by the environmental impact of a project. In fact, often the buffer zones determined by technical experts are inadequate. Furthermore, downstream water users are often not considered in assessment of impacted peoples. It is worth noting that social impacts do not necessarily decrease in intensity with distance from the project site. People are connected by a vast array of linkages and networks. Projects also can often have a wide logistics corridor and complex value chains (with backwards and forwards linkages). Defining a 'social area of influence' does not necessarily require the articulation of a geographic boundary. Instead, the social extent of the project can be determined through a combination of stakeholder analysis and social mapping, and through an iterative process of understanding the social, economic, political and environmental changes induced by the project and the livelihoods and networks of potentially impacted people.

### **Task 4:** Gain a good understanding of the communities likely to be affected by the project by preparing a Community Profile which includes: (a) a thorough stakeholder analysis; (b) a discussion of the socio-political setting; (c) an assessment of the differing needs, interests, values and aspirations of the various subgroups of the affected communities including a gender analysis; (d) an assessment of their impact history, i.e. their experience of past projects and other historical events; (e) a discussion of trends happening in those communities; (f) a discussion of the assets, strengths and weaknesses of the communities; and (g) optionally the results of an opinion survey. This task is typically called profiling.

Understanding the local cultural context is essential for the success of the SIA and the project. It is important to appreciate that different societies have different cultural values, with different understandings about how things should be done. These differences can pose many challenges for project development and for the conduct of SIAs. A common occurrence is that outsiders (i.e. project managerial staff and sometimes SIA consultants) tend to presume that local people value the same things they (the outsiders) do. They also often presume that all local people have common concerns. This mismatch can be exacerbated by the use of economic models and other conceptual frameworks with their implicit and sometimes explicit ideological and cultural positionings. This misrepresentation can lead to problems in the conduct of the SIA and the development of the project. It can also lead to poor analysis of the impacts and poor assessment of appropriate mitigation and benefit enhancement strategies. Thus, gaining a good understanding of the local context – by, in addition to other methods, having effective participation processes (see Task 6) – will greatly assist in the conduct of the SIA and in project implementation.

The subheadings below discuss different aspects that need to be considered in order to gain a good understanding of the local context. The analysis of the local context is usually written up as a 'Community Profile'. The first step is a thorough stakeholder analysis. While normally one document is produced, if it is discovered that there are more than one disparate affected communities, the Community Profile document may need to have subsections describing the different communities.

**(a) a thorough stakeholder analysis**

One of the failings of many impact assessments is the inadequate identification and participation of all the potential stakeholders (also called interested and affected parties or IAPs). This is a problem because without adequate awareness of all the stakeholders (and rights-holders), some of the social impacts may not be properly considered. The types of people who are likely to be stakeholders in most projects typically include:

- Residents in the immediate impact zone, the affected area, especially those who will be physically or economically displaced as a result of the project;
- People in the host communities where displaced persons relocate to (either as a result of a planned resettlement or through their own migration);
- Nearby communities as well as more distant residents whose livelihoods may be threatened/affected as a result of the project;
- People who will be affected by associated works, such as irrigation channels, quarries, roads, railways, and transmission line corridors;
- Construction workers and their families;
- People who migrate to construction areas in search of work or other benefits they perceive may arise due to the project (a process known as project-induced in-migration or the honeypot effect);
- People in communities near where construction workers or other in-migrants will be located;
- Non-resident Indigenous and other land-connected peoples who may have spiritual attachment to the land/river and/or native title to land in or near to the construction site;
- Local, national and international NGOs (for example, conservationists) who may be interested in the ecological or heritage values that may be threatened by the project;
- Other stakeholders such as the developer and associated contractors, regulatory agencies, local regional and national governments, funding or development agencies, as well as the intended beneficiaries.

No generic listing will ever be adequate in all cases because there will always be locally-specific groups and locally-specific circumstances of the local cultural context. It is also important to realise that these stakeholder groupings contain considerable variation within them, including gender differences, and differences based on age and vulnerability, etc (discussed further below). To give one example of how local context can be important, in one resettlement process, there was a government-mandated process of compensation for impaired means of earning income and/or lost assets for resettled people that involved payments into the bank accounts of the male heads of households. It was thought that this procedure would be appropriate. However, in that country polygamy is common, and a significantly-affected group of people were the second, third, and other wives of these men. These women were also negatively affected by the project, but were much disadvantaged by this compensation procedure. They had not been considered in the assessment of social impacts and compensation procedures. A better understanding of the local cultural context would have led to an awareness of this aspect of local life and would have suggested a different process of compensation.

**For more information**, refer to:

IFC 2007 *Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets*. Washington, DC: International Finance Corporation. **http://www.ifc.org/wps/wcm/connect/938f1a0048855805beacfe6a6515bb18/IFC_StakeholderEngagement.pdf?MOD=AJPERES**

**(b) a discussion of the socio-political setting**

An important aspect to understanding local communities is understanding their socio-political context. The attitudes, values, social development goals of people, as well as how they are likely to respond to the project and to likely impacts, as well as their level of trust in government, the project developer and the SIA process itself are very much influenced by the socio-political setting. The recent political history of a place, the extent of open or latent conflict that might exist, whether it is a post-conflict society are all important considerations. Knowing the cultural characteristics that influence whether people will be prepared to talk openly or not will have a bearing on how community engagement processes should be designed. The functioning of the legal system and people's awareness of their rights and access to legal remedy are also relevant considerations.

**For more information**, refer to:

Kemp, D. 2011 "Understanding the organizational context", in Vanclay, F. & Esteves, A.M. (eds) *New Directions in Social Impact Assessment: Conceptual and Methodological Advances*. Cheltenham: Edward Elgar, pp.20-37.

**(c) an assessment of the differing needs, interests, values and aspirations of the various subgroups of the affected communities including a gender analysis**

It should be noted that not only are there different stakeholder groups with differing interests (such as those listed above), there will likely be differences between individuals in the same stakeholder group. An affected community might be segmented into people (perhaps working age men) who may be notionally in favour of the project because they consider that jobs might materialise, whereas other people (perhaps some older women) may be concerned about the social and cultural impacts. Young people in general often have different views than older people, especially in relation to traditional cultural values and appropriate ways of doing things. Establishing the views of each subgroup can be complex. Sometimes, multiple different organisations or individuals may seek to represent a constituency, and it may be difficult for an SIA practitioner to determine which organisation has greater legitimacy for each constituency. In fact, it is always desirable for the SIA process to do its own primary data collection amongst each social group and not rely on the statements of political representatives or group leaders who may engage in strategic tactical action rather than faithfully present the views and concerns of the constituency.

The notion of 'residents' must be deconstructed. Residents are rarely an homogenous group, and may include long-term residents (oldtimers or locals), recent arrivals (newcomers), and people who use the location as a dormitory suburb (that is, they work elsewhere) and may not have strong ties to where they live. It may also include second home owners, including people who are 'weekenders' and/or those who regularly holiday there. Depending on the locational context, there may be informal settlements, including illegal immigrants. While project managers may not consider these groups as being legitimate stakeholders, it is important that the SIA practitioner be aware that from a human rights perspective, these people are still rights-holders, and therefore the impacts they experience must still be considered. There can also be different types of people who don't actually live near the project site, but nonetheless will potentially be affected by changes at the site. These may include workers, especially FIFO (fly in, fly out) and DIDO (drive in, drive out) workers, visitors, daytrippers, commuters and shoppers. Consulting them about changes and actively taking their concerns into account may well lead to improved relations with these stakeholders and better decisions.

Village (or community) and household are often used as the units of analysis because impacts occur at different levels – at an individual level, household level, and at the group or community level. Some impacts affect individuals as individuals. Other impacts affect households (or similar family or domestic units) because they affect family structure and functioning. Other impacts affect society as a whole, and/or the adequacy of social institutions. Ultimately, however, all impacts are experienced by individuals, although individuals experience impacts in different ways depending on their social situation. A gender analysis is essential to understand how women and men are differentially affected, however, it is also vital to appreciate that women are not homogeneous, and therefore care must be taken to appreciate the diversity in situation and experience of different types of women, as well as the different types of men. When it is predicted that the level of work effort required to survive will increase because of changes to the environment brought about by a particular project, it is the women who will often bear the brunt of



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increased workloads. If men leave their homes and villages for work at a distant workplace (a mine or a factory, or even to go to the city in search of work), women face increased workloads. Even when men earn money, cash is often expended on consumer goods and may not lead to a reduction in women's workload. If entrepreneurial activities are promoted to allow villagers to earn additional cash income, it is usually the women who experience an increased workload producing that income. It can be argued that many planned interventions have worsened the position of women. In fact, even enhancement activities designed to improve community wellbeing can worsen the position of women because of the gendered distribution of workload.

Understanding why people are opposed to a project is useful. People will at least appreciate that their concerns have been listened to, even if nothing can be done in relation to their concerns. However, many times things can be done to address people's concerns and opposition. Perhaps their opposition is based on misinformation or an incorrect assumption. Correcting this information and/or dispelling the incorrect assumptions can greatly reduce people's concerns. Sometimes opposition to a project occurs because of concerns about matters somewhat unrelated to the project itself. For example, in one situation, some people were indirectly opposed to a particular project because they feared it would increase surveillance which would detect their illegal fishing activities and/or limit their access to a favourite fishing location.

**For more information**, refer to:

Eftimie, A., Heller, K., & Strongman, J.. 2009 *Mainstreaming Gender into Extractive Industries Projects: Guidance Note for Task Team Leaders.* (Extractive Industries and Development Series #9). Washington, DC: World Bank. **http://siteresources.worldbank.org/EXTOGMC/Resources/eifd9_gender_guidance.pdf**

**(d) an assessment of their impact history, i.e. their experience of past projects and other historical events**

Although project staff and companies may believe they are not responsible for the past actions of other projects in a region (what are often called legacy issues), from the perspective of local communities unresolved past issues will very often need to be addressed before they are willing to consider a new project. In the case of an acquisition, the purchasing company might think it is not responsible for the actions of the previous operating company, but to the community it is all the same project and they will certainly hold the current operator responsible for the issues they currently experience even if they arise from the actions of the previous operator or the exploration company. Where a community has a legal basis to approve or reject a project (i.e. FPIC), it will be essential for a company to address legacy issues to order to obtain its social licence (i.e. consent from the community). However, even in other situations, if a company is genuine about its respect for community, addressing past social issues will go a long way to building trust and good relations, and provide a firm basis for a social licence to operate. Saying sorry for past harm that has been experienced is part of demonstrating respect (see Box 7). An awareness of past issues is also essential to be able to fully understand the likely reaction of a community to the new project, and in planning mitigation and enhancement measures.

**(e) a discussion of trends happening in those communities**

It is really important for the SIA to have a good understanding of all the things that are happening in a community. This is important for two primary reasons. Firstly, cumulative impacts can only be understood by knowing what else is happening in the region. Secondly, part of SIA is the establishment of a baseline and the construction of a forward scenario about what is likely to happen to the community without the project. This is needed because the measurement of change due to the project is not necessarily the absolute difference in the values of the baseline variables between commencement of monitoring and the present time, but between what has happened versus what would have happened without the project (i.e. the counterfactual). Thus, a good understanding of the trends (social change processes) that are happening regardless of the current project is necessary.

## BOX 7: Example of good practice in saying sorry

A mine in Australia, which commenced production in the 1980s, involved exploiting a cultural heritage site of significance to Aboriginal women. Although an agreement with some male Traditional Owners had been reached allegedly consenting to the destruction of the site, that agreement was inadequate in terms of the process by which it was developed and the benefits it provided to the local Aboriginal community. Despite ongoing concerns by the local community, the operating company did little to address the issues. It took a change in mine ownership and in senior site staff before a new attitude of respect came into company culture, primarily because the approval of the Traditional Owners was needed for a proposed expansion. A new community-based agreement making process was initiated which empowered the Traditional Owners by supporting their ownership of the process. The process enabled a thorough consideration of the distress caused by the past conduct of the mine and the various state and federal governments. Traditional Owners articulated that legacy issues needed to be addressed and demanded that a formal apology from the mine be made before they would agree to any future relationship. The company complied with these demands and an appropriate traditional (smoking/cleansing) ceremony was performed. Eventually the Traditional Owners agreed to the proposed expansion. The company has heralded the process as a learning experience for them and has widely championed the story of their epiphany. Other key aspects of the new agreement included:

- Aboriginal control over all land use to enable protection of sacred sites and heritage areas;
- a compulsory program of cross-cultural training for all mine employees and contractors;
- recognition of local customary practices and their integration into mine activities and procedures;
- employment and training programs to increase Aboriginal participation in the mine workforce;
- unlimited access of Traditional Owners to non-operational areas of the mine lease;
- adoption of a regime of environmental co-management;
- commitment to Traditional Owner participation in eventual closure planning and decommissioning; and
- a revenue sharing model providing a substantial contribution to the local community.

**(f) a discussion of the assets, strengths and weaknesses of the local communities**

Understanding a community means knowing what the various elements of the community want, how they see their community, and their vision for the future of their community. It is also about knowing their values and spiritual beliefs, which is essential for understanding how impacts will be experienced. A full understanding of a particular community also requires a knowledge of community assets, resources, strengths and weaknesses. This will assist in predicting impacts and the experience of those impacts by the community, as well as in conceiving appropriate strategic social investments and other community development initiatives. Undertaking a SWOT analysis as part of a community forum can be a useful precursor to a discussion about what contributions a project might make to a community.

**For more information**, refer to:

Chambers, R. 1997 *Whose Reality Counts: Putting the First Last.* London: Intermediate Technology Publications.

Kretzmann, J. & McKnight, J. 2005 *Discovering Community Power: A Guide to Mobilizing Local Assets and your Organization's Capacity.* Evanston, IL: ABCD Institute. **http://www.abcdinstitute.org/docs/kelloggabcd.pdf**

Oxfam 2013 *The Sustainable Livelihoods Approach: Toolkit for Wales*. **http://oxfamilibrary.openrepository.com/oxfam/bitstream/10546/297233/8/sustainable-livelihoods-approach-toolkit-wales-010713-en.pdf**

**g) optionally the results of an opinion survey**

There are a range of social research methods that can be used to get a sense of community concerns and opinions about the project. These methods have their various pros and cons, and varying accuracy (reliability and validity). While key informants sometimes do have a good awareness of community concerns, there are times when they are completely out of touch. While focus groups are frequently used, there are always concerns about the extent to which focus group participants are representative. Thus, in societies where surveys are culturally appropriate, commissioning an opinion survey with a sample of sufficient size to have reasonable statistical power can be a good way to assess feelings about a project of people in a defined region. These surveys can be repeated at regular intervals to track changes in perceptions, issues and the perceived social license of the project.

### Task 5: Fully inform community members about: (a) the project; (b) similar projects elsewhere to give them a sense of how they are likely to be affected; (c) how they can be involved in the SIA; (d) their procedural rights in the regulatory and social performance framework for the project; and (e) their access to grievance and feedback mechanisms.

To be consistent with expected transparency, to treat communities with respect, and to gain a social licence to operate – especially in situations where SIA is part of an FPIC process – it is necessary to ensure that the affected communities are fully informed about the project and understand how it will affect them. Furthermore, for community input to be useful to assist in project design, it is also desirable that the affected communities be fully informed about the project. In societies with experience with similar projects, it is likely that sufficient capacity to understand the likely consequences of the proposed project will exist within the host community. However, where the project is conceptually new to the intended host communities, in order to assist their full understanding it may be necessary to provide information about how similar projects affected host communities elsewhere. A failure to do this could be considered to be a breach of FPIC, and in any case, such anticipation will assist in planning for and coping with the changes that will arise. Thus, arranging site visits to other projects could be useful to ensure that the host communities are fully informed and capable of understanding the likely impacts of the planned project.

Discussing and negotiating how the host communities will be involved in the SIA and the project generally is necessary. Disclosing the statutory and procedural rights participants have is essential, but ideally the proponent and SIA practitioner will go beyond the minimum requirements to enable a greater degree of participation (and preferably deliberation) by the affected community members.

Another component of full disclosure relates to the possibilities for redress and complaint (in other words, grievance mechanisms) that are available to affected peoples. While the design and implementation of grievance mechanisms is discussed under Task 18, participants in an SIA and people affected by a project need to be informed from the beginning of project discussions about the mechanisms available to them to raise any grievances they may have and/or provide feedback. Principle 31 of the UNGP, which lists effectiveness criteria for non-judicial grievance mechanisms, indicates that such mechanisms must be accessible to all stakeholders, which in the first place means that the mechanism must be known to them and accessible to them. Good practice in all organisations includes ensuring that all stakeholders are knowledgeable of their ability to, and about how to actually access such mechanisms.

### Task 6: Devise inclusive participatory processes and deliberative spaces to help community members: (a) understand how they will be impacted; (b) determine the acceptability of likely impacts and proposed benefits; (c) make informed decisions about the project; (d) facilitate community visioning about desired futures; (e) contribute to mitigation and monitoring plans; and (f) prepare for change.

Effective participatory processes are essential for SIA. Even though SIA consultants will likely have extensive experience and can reasonably determine what many social impacts of a given project may be, they will never be able to know precisely what the meanings and/or consequences of certain activities will be to local people. For example, sacred sites or other sites of local historical or cultural significance may not be known or be self-evident to outsiders. In many other ways, too, it will be impossible for the SIA consultants to know what the local impacts will be without input from local people about how they use the environment, what is important and meaningful to them, and want they think about the various changes in the landscape, their livelihoods and social structures.

The acceptability of likely impacts and of proposed enhancement measures must be determined by local people themselves, otherwise such decisions would have no legitimacy. It is essential that local communities have sufficient time and resources to be able to deliberate about the likely social impacts that will be experienced. This necessitates the time and resources to identify, to learn about, and consider or reflect upon the likely changes. Since first reactions are likely to be different to considered responses, time is needed to ensure that the learning process and deliberation can take place. Since individuals in a given location will rarely be unanimous on their view on things, time is also needed to allow a community to consider its aggregated response in its own culturally-appropriate way.

Such deliberativeness is necessary for community approval to qualify as being free, prior and informed consent (FPIC). According all communities (non-Indigenous as well as Indigenous) with the power to provide or withhold broad-based consent (i.e. akin to FPIC) is international best practice and demonstrates respect to local communities. Without participatory and deliberative processes, it would be impossible for a project to claim it had such support or a social licence to operate.

A future vision for local communities needs to be made by local people themselves in a deliberative way. It is important that there be a future vision because the acceptability of projects and of the impacts and benefits they create is linked to perceptions about the future and whether a project is consistent with that image or not. Where there is no articulated future vision, people will in any case have a self-image (sometimes consciously held and sometimes sub-conscious) of their desired future. Without negotiation of the future vision and a discussion of strategies to plan to achieve that vision, it will be extremely unlikely that it will be reached. Also, individuals in a location will hold different conceptions of the future, thus a process for negotiating the various ideas will be needed to arrive at a broadly-endorsed vision.

Participatory processes are also needed to assist people in preparing for and coping with change. When change is imposed it will often be resisted and may be regarded negatively. Conversely, when change is negotiated and considered acceptable, it will be tolerated and maybe viewed positively. Thus, whether a change is considered as a negative impact or not, often has to do with the legitimacy of the process that brought about the change. However, even changes that are accepted can still create negative impacts and harm. A participatory process will assist in identifying coping strategies, in correcting misinformation and prejudices, and in identifying acceptable mitigation strategies.

Participatory processes can also be important in terms of creating positive situations in which local people are willing to contribute information that might be of use to project developers. This information can include local knowledge that may be profoundly useful (and valuable) to project staff in terms of understanding the local environment and site characteristics. This is especially the case in developing countries where official data sources may be limited. Having local knowledge about the likelihood, frequency and severity of flooding, hail, storm events, and flood peaks, as well as the locations of frequent lightning strikes, etc, could lead to considerable cost-savings to the project where this information is taken into consideration. However, without a positive, respectful situation, why would local people make the effort to offer this information?

During the SIA consultation processes, SIA consultants have the opportunity to start engaging with communities regarding their expectations about ongoing community relations, grievance mechanisms, mitigation measures, and their potential contribution to the monitoring of social impacts. Recommendations made by the SIA practitioners based on this community input should be considered when these aspects are further developed. Process is just as important as outcome, and an inclusive, participatory process can be key to successful implementation.

While evaluations of planned interventions around the world reveal that successful interventions are ones in which there has been considerable participation, it should be noted that participation is not a universal panacea and cannot guarantee success of the SIA or of the project. There may well be unresolvable conflict due to the way in which a planned intervention divides a community into winners and losers, or because of background tensions that preceded the current intervention. An understanding of the local history is essential, especially in relation to latent conflict. It can also not be assumed that, even if a participatory process is made available, local people will choose to participate. Whatever the intention of the project staff, local people may not think it is not a sincere or genuine process, they may not feel that their views will be taken seriously and thus not worth their effort, or they may not feel it is worthwhile or necessary. In societies without a culture of participation, special efforts may be needed to encourage people to participate and facilitation in how to participate could also be required, especially for vulnerable groups in disadvantaged positions. Participatory processes must be available to all. To ensure inclusivity, it is necessary to devise ways to include vulnerable groups and the worst-off members of society.

## Task 7: Identify the social and human rights issues that have potential to be of concern (i.e. scoping).

Scoping can be defined as the process of identifying the main issues of concern as well as determining the interested and affected parties (refer to Task 4) for a particular planned intervention. It is a preliminary process that produces an interim list of issues to be considered that are later properly assessed (Task 9). The reason for the two stage process is to ensure transparency and inclusivity, especially because it is usually not immediately obvious what the social impacts might be. This two stage process also allows for modification to the timeframe and costing of the SIA, especially if anything unexpected might arise during the scoping process. Scoping is an open, ongoing process that responds to information. Inputs to scoping (i.e. suggestions of impacts to consider) should come from a range of sources including a desktop review of similar cases elsewhere, expert judgement, and most importantly suggestions from local people. The initial interviews done as part of the profiling process can provide ideas which can be a good starting point. However, undertaking community-based workshops to generate input for the scoping process is a good idea. The scale and location of these workshops should, of course, be responsive to the context. For example, in communities where it is not considered appropriate for women to speak publicly, separate meetings with women may be necessary to ensure that any issues or potential impacts they have are able to be recorded an included in the scoping process.



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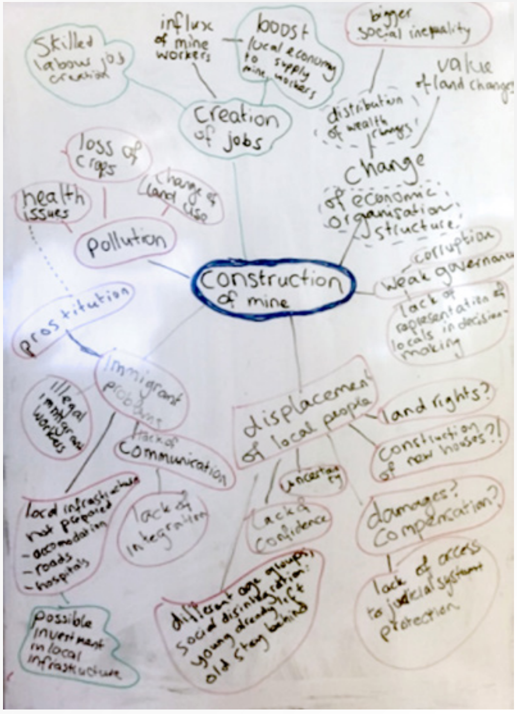
It is essential to be very open in the scoping process to ensure that all possible impacts are considered. The assessment that comes later (Task 9) is where the actual determination of the likely impacts is undertaken. To ensure that all likely impacts are identified, it is necessary that all possible impacts are included in the scoping process. It is important that the scoping process is undertaken for each of the major activities comprising the overall project (see Task 1). For example, the impacts of a mine may include the impacts on people living in communities along the railway line to the port hundreds of kilometres away from the pit. In many developing countries, the railway lines go right through the middle of villages, with people frequently crossing the tracks, and often children playing on the tracks (see Box 8).




**Undertaking a mindmapping process is useful in the scoping process.**

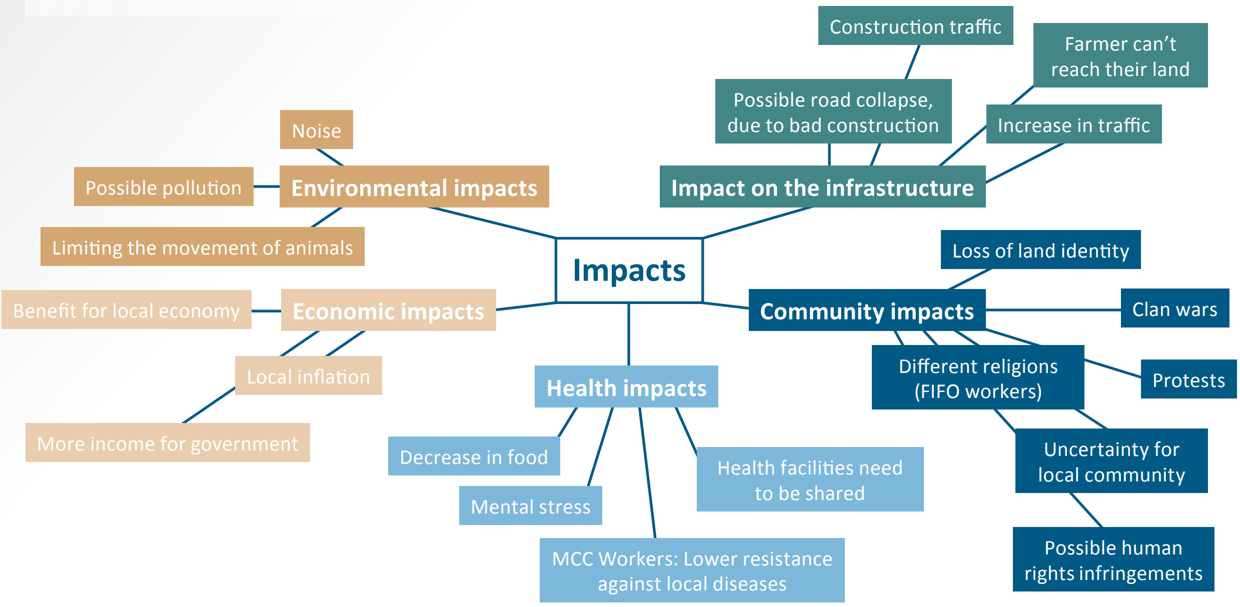



**Figure 6:** Examples of mindmaps

**Source:** University of Groningen students (used with permission)



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## BOX 8: A Case Study for Reflection

A mining company planning on constructing a new mine  in a certain developing country plans to build a railway line to transport ore to the nearest port several hundred kilometres away. The railway line will be part new construction (greenfield) and will also utilise an existing railway line that traverses a densely populated area and many townships. Partly in response to government control to ensure rationalisation of infrastructure development and partly as result of the company's commitment to benefit enhancement, large sections of the railway line will not be used exclusively by ore trains – other trains with general freight, fuel, and passengers will also utilise the railway line. While this is a benefit, it also means that the total volume of train traffic will be perhaps twice the number of ore trains. Should this be included in the impact assessment for the mine?

Some people in trackside communities are worried about dust coming off the ore wagons. This is a legitimate concern. The ore wagons are uncovered, however a dust suppressant will be applied. They are unsure whether the dust suppressant will be properly applied, and whether it will last the distance especially in the harsh conditions with high temperatures and heavy downpours. Investigative research suggests that dust emissions are less of a health risk than the diesel fumes from the locomotives, and negligible in relation to the myriad of other sources of hazard and dust people in the trackside communities are exposed to. Nevertheless, despite the expert evidence, the local people are not convinced, and it remains one of their concerns. Is it a social impact?

There is also concern about the fact that some trains will carry dynamite for the mine and fuel wagons for the mine and communities along the railway line. While this presents a risk, the risk is much lower when these goods are carried as railway freight than when they are carried by road on semi-trailers or trucks. The biggest risk posed is to the people in the communities with the existing railway line, which will see track usage increase from one train per day with an average wait time to cross of 5 minutes or less to more than one train per hour with an average wait time of 15 minutes or so. This will create disruption to daily living, noise nuisance, and the risk of accidents.

**Figure 7: In many developing countries, houses can be very close to train tracks**

**Source:** Wikipedia, creative commons license



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## Task 8: Collate relevant baseline data for key social issues.

The community profile (see Task 4) and baseline data are related but different concepts. The profile is a rich, qualitative description of the affected communities including a discussion of trends and issues. The baseline is a carefully-selected set of social indicators (social variables) with accompanying quantitative data for the specified communities. The baseline refers to a point of comparison – in other words, to the data (social indicators) about the affected communities that will be used as the reference data against which to measure the impacts of the project as it develops, and/or to determine the adequacy or otherwise of existing facilities. Ideally the data should be from the pre-impact state, but this is not always possible. The baseline data needs to cover all the relevant issues, not just things for which data are easily available. Thus, careful determination of the social issues that will be included in the baseline is necessary. For each of the key social issues, an appropriate variable will need to be determined and data collected.

While for some variables baseline data might be able to be extracted from pre-existing data (e.g. secondary data such as census data, etc), for most variables existing data will not be available or will be at the wrong scale, or will be too dated to be of much use. Thus adequate baseline reports require considerable effort in identifying critical issues, determining appropriate variables, and data collection.

The baseline data is an indication of the pre-existing state. In addition to baseline data, for each indicator of a social impact identified as potentially significant, an appropriate benchmark and target value will need to be determined. The benchmark value refers to an external point of comparison, such as an international standard (such as a World Health Organisation recommendation), industry norm, or a similar situation elsewhere such as a partner site or competitor. Once a benchmark is determined, a target value can be set. The target refers to what is hoped to be achieved at the project site. Sometimes the target might be equivalent to the benchmark value, however a different target can also be set depending on the context. For example, a company that wants to be a world leader might set a more stringent value for the target. Alternatively, when it is known that it is likely to be impossible to achieve the benchmark, a lower target might be set. An example of this might be the number of medical doctors (physicians) per 10,000 head of population. In many rural areas, it may not be realistic to expect the same number as the average in urban areas.

## PHASE 2: PREDICT, ANALYSE AND ASSESS THE LIKELY IMPACT PATHWAYS

### Task 9: Through analysis, determine the social changes and impacts that will likely result from the project and its various alternatives.

The scoping process (Task 7) provides an initial list of issues for the SIA practitioner to investigate. This is where the actual studies are undertaken to determine what is really likely to happen and whether a perceived impact will actually eventuate. It needs to be an open process allowing new issues to be added to the list of matters to be considered. It also needs to cross-reference with the other impact studies being undertaken. For example, the EIA might reveal changes to the physical environment or to the provision of ecosystem services that did not arise in the scoping process. A key issue is that many projects apply for initial regulatory approval for a small operation even though there may be expansion plans being prepared. The assessment of impacts needs to consider reasonably foreseeable expansion of the proposed project, as well as other projects and support industries that may also develop.

Some potential impacts may be genuine concerns of local people (perceived impacts). On investigation, it may turn out that some of these concerns are not likely to eventuate. While these issues are concerns of local people, they will still affect the way these people relate to the project and will affect their feelings and behaviour. Thus careful engagement needs to occur to ensure that the people who hold these concerns feel that their concerns have been seriously considered. The important concept is that their concerns are legitimate social impacts even if not supported by technical analysis. Where SIA is seen as the process of managing social issues, the SIA team can identify concerns and work with local people to address these concerns.

### Task 10: Carefully consider the indirect (or second and higher order) impacts.

In addition to the direct impacts, the indirect, second and higher order impacts also need to be considered and analysed. Careful attention needs to be given to thinking what these may be, especially because they may at first not be obvious. The mindmapping process (see Task 7) can help in thinking about the impact pathways, but in the analysis component of the SIA (Tasks 9, 10, 11), these impact pathways needs to be substantiated through analysis. As the analysis is ex-ante, i.e. a prospective assessment of what might happen, analysis does not necessarily comprise collecting and analysing data; instead it requires a comparison with experiences elsewhere, having experts input into scenario analyses and the use of reasoned thinking. Figure 8 is a good model to assist in reasoned thinking about indirect impacts and impact pathways.

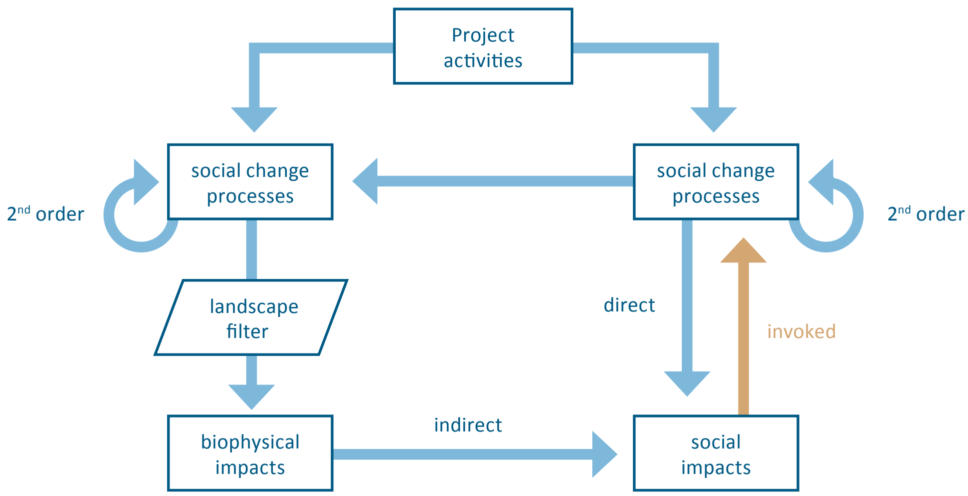


**Figure 8: Model for thinking about indirect impacts and impact pathways**

**Source:** modified from Slootweg, R., Vanclay, F. & van Schooten, M. 2001 Function evaluation as a framework for the integration of social and environmental impact assessment. *Impact Assessment & Project Appraisal* 19(1), 19-28. **http://dx.doi.org/10.3152/147154601781767186**



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In Figure 8, each major activity comprising the project is considered in turn. The path to the experience of social impacts may be directly via a social change process, or it might be through a change to the biophysical environment, such as environmental pollution. The invoked arrow refers to the way people will likely respond to the experience of an impact and to what social changes processes will then occur, thus causing further impacts. A social change process can also lead to environmental changes which then cause more social impacts. And so it goes on.

One important issue to consider is project-induced in-migration, sometimes called the 'honeypot effect' or influx. In addition to those workers directly recruited by project staff and brought to the project site, large projects tend to attract many other people seeking economic opportunities such as jobs with the project or to provide a range of goods and services to the project and its employees. Depending on the situation, this can considerably increase the number of people who actually move into an area and the extent of impacts experienced by the host community.

**For more information**, refer to:

IFC 2009 *Projects and People: A Handbook for Addressing Project-Induced In-migration*. Washington, DC: International Finance Corporation. **http://commdev.org/files/2545_file_Influx.pdf**

Vanclay, F. 2002 Conceptualising social impacts. *Environmental Impact Assessment Review* 22(3), 183-211. **http://dx.doi.org/10.1016/S0195-9255(01)00105-6**

## Task 11: Consider how the project will contribute to the cumulative impacts being experienced by the host communities.

It is important to consider not only the direct and indirect impacts of the current project, but also to consider how the project will contribute to other impacts being experienced by the host community. All impacts have a cumulative dimension. Every impact will be experienced differently depending on the current state of the socio-environmental system; impacts may aggregate (or disaggregate) over time or space and interact to produce new impacts. Impacts may aggregate and interact as a result of actions within and between projects, and from past and future activities. Socio-environmental systems respond to impacts through feedback or governance processes (see Figure 9).

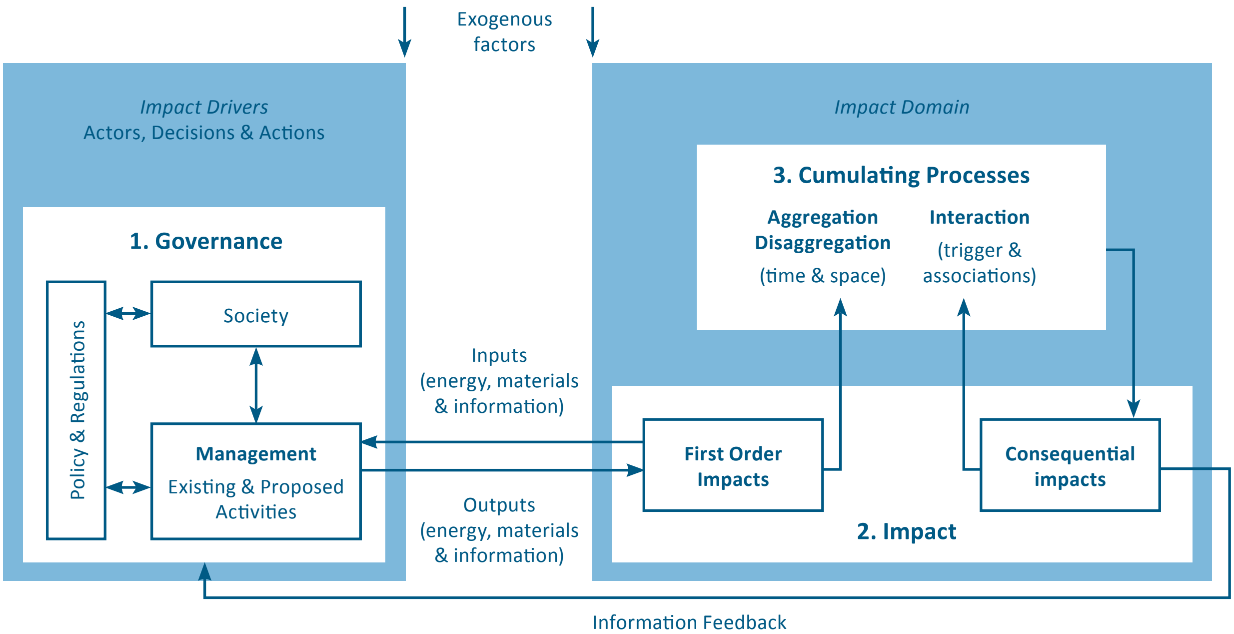


**Figure 9: Cumulative impacts**

**Source:** Franks, D., Brereton, D. & Moran, C.J. 2013 The cumulative dimensions of impact in resource regions. *Resources Policy* 38(4), 640-647. **http://dx.doi.org/10.1016/j.resourpol.2013.07.002** (used with permission)



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The cumulative dimensions of an impact cannot be properly understood or managed by solely focusing on the activities of an individual project or development. An understanding of the socio-environmental system is needed, which will necessarily require some form of prioritisation to consider those issues of most significance. Integrative concepts such as sustainable livelihoods, ecosystem services, and social development can help to uncover the links and interactions between impacts.

The assessment and management of cumulative impacts can be aided by:

- understanding the processes of impact causation (through methods such as impact pathway analysis) from the perspective of the people and environments experiencing impact;
- understanding trends, particularly in baseline studies to capture the cumulative impacts of past activities;
- consideration of associated facilities, and past, present and foreseeable future activities;
- forecasting and scenario analysis.

Any proposed management strategies will need to respond to the scale of the system in which the impacts are occurring. Coordination and collaboration with other contributors of impact can assist in addressing priority impacts. Examples of collaboration include multi-stakeholder monitoring, information exchange, networking, strategic planning or collective management of data.

**For more information,** refer to:

IFC 2013 *Good Practice Handbook on Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets*. Washington, DC: International Finance Corporation. **http://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/ifc+sustainability/learning+and+adapting/knowledge+products/publications/publications_handbook_cumulativeimpactassessment**

Franks, D.M. et al. 2010 *Cumulative Impacts: A Good Practice Guide for the Australian Coal Mining Industry.* Brisbane: Centre for Social Responsibility in Mining. **http://www.csrm.uq.edu.au/docs/CSRM%20SMI%20Good%20Practice%20Guide%20document%20LR.PDF**

### Task 12: Determine how the various affected groups and communities will likely respond.

Whereas Task 9 was about identifying the likely social impacts that will be experienced, here consideration is given to how the various stakeholder groups will likely respond to those impacts. Because the different groups of people will be affected in different ways, they will likely respond in differing ways to those impacts. For example, for a proposed new mine in an area of southern Africa dominated by game farming and tourism, it would be quite likely that the local general population would be largely in favour of the mine because of new job opportunities created in an area where unemployment is high. However, the (rich) landowners may well be opposed to the mine because they will experience visual and landscape impacts, and consequent changes in the regional identity and their sense of place. The mine is also likely to have a negative impact on tourism in the area, which may affect the income of the game farm operators. Therefore, unless effort is made to engage the game farm operators, they may use their social and political capital to obstruct the project.

Another example concerns a rural electrification scheme. Even if it was being done with good intent to supply power to households that currently do not have access to electricity, organised local opposition to the project could occur if, for example, there was a feeling that local people should be employed on the project. This example shows that a development project can't always assume it will automatically have a social licence to operate just because it ostensibly is bringing benefits.

Understanding the social response is necessary partly to determine the risk to the project, but also to consider what the indirect (second and higher order) impacts might be. For example, in one case a development was planned which would destroy land of high cultural significance to the local Indigenous group. It was therefore expected that there would be some local opposition, however the project developers thought they could provide sufficient benefits to compensate for this and win approval. What they did not count on was the fact that the local traditional healers (shamans, sangomas) were strongly opposed to the destruction of the site, and they forbade anybody from the local tribal group to work on the project, and they cursed the project suggesting that it would be very prone to fatal accidents. This meant that no local people went to work for the project, resulting in few benefits to the local community. The project had to import workers from outside the region, which led to considerable tension between the workers and the local people. The presence of the imported workforce led to a range of other impacts on the local community making them much more worse-off than they were before. Continued protests by the local tribe eventually drew international attention and condemnation of the company for alleged human rights abuse.

There are many possible responses individuals and communities might take in reaction to a particular impact, depending on the way they experience the impact and whether or not they consider it to be fair and reasonable. Responses can range from acceptance and/or adaptation of their life to accommodate the changed situation to vigorous objection and protest. Sometimes, people's daily activities might change in ways that lead to more impacts.

## BOX 9: Social impacts of a major dam project in the mountains

In the case of a major water project comprising several large dams, although initially there were positive perceptions of the project by local people, in the project's later stages much opposition arose due to the negative impacts they began to experience. Local people considered that many of the promised benefits had not eventuated. Some training programs were so poorly managed that, even though they were intended to help local people get jobs on the project, they were provided far too late in the life of the project and/or did not teach the skills that the project needed. Another complaint was that too much compensation was in the form of replacement food and cash, and consequently many people did not have meaningful things to do with their lives. Thus, even though they had been financially compensated for lost income and disrupted livelihoods, to maintain some sense of normality, some people tried to continue their normal day-to-day activities, but these were now negatively affected by the water bodies and access roads, etc. The alpine livestock herders complained that their work was harder now. The dams had drowned the valley floors which were used by them as winter pastures (when they could not be high up on the mountains). The loss of these winter grazing lands as well as the submerging of caves they used for shelter during particularly cold weather meant that their livestock did not gain as much weight and their work was less pleasant. They also experienced a sense of sadness because of the changing landscape. The loss of land and associated vegetation also led to an unconsidered social impact – traditional healers complained that they had lost access to their medicinal plants making it harder for them to practice. Another issue emerged. Although anticipated, people did not fully comprehend the implications of the inundation. Previously neighbouring villages now became divided by the reservoirs, resulting in villagers no longer being able to see their relatives, attend to their fields, or conduct business across the valley as they had done before.

**Figure 10: Mountain livestock herder**

**Source:** Michael Williams, Flikr creative commons copyright

## Task 13: Establish the significance of the predicted changes (i.e. prioritise them).

After all the impacts have been assessed, it is then necessary to prioritise them for action. In impact assessment speak, this is called 'establishing significance', 'significance assessment' or 'significance determination'. In effect, criteria for establishing significance need to be determined and each impact rated (or ranked) on the basis of those criteria. There are several methods that can be used to do this. While Multi-Criteria Analysis is frequently used, it is also possible to use a risk assessment methodology. This has the advantage of being in a language that companies are used to. Typically this involves assigning a consequence score and a likelihood score for each risk (or potential impact) (see Figure 11). In industry usage, the risks are commonly assessed from the perspective of risk to the business (business risk), but there is no reason why the approach cannot be used as a way of assessing the potential impacts to the community (social and environmental risk). In fact, several risk assessments can be made, for example from the perspective of each of the stakeholder groups. The assignment of risk can also be done in a workshop environment with the stakeholders themselves making the assessment.

| | | Consequence Level | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| **Likelihood Level** | Descriptor | Insignificant | Minor | Moderate | Major | Catastrophic |
| **A** | Almost certain | A1 | A2 | A3 | A4 | A5 |
| **B** | Likely | B1 | B2 | B3 | B4 | B5 |
| **C** | Possible | C1 | C2 | C3 | C4 | C5 |
| **D** | Unlikely | D1 | D2 | D3 | D4 | D5 |
| E | Rare | E1 | E2 | E3 | E4 | E5 |

**Figure 11: Risk assessment framework.**

**Risk Rating** Low Moderate High Extreme

In formal risk assessment, empirical (quantitative) measures are usually used to determine the actual assignment of likelihood and consequence. However, this can also be done subjectively by a group of people considering each issue, and seeking more information when there is high uncertainty.

While risk rating is a way of determining significance and establishing priorities for action, it should be noted that even small things can affect the way some people in the local communities feel about a project. Sometimes the small things that are insignificant in risk analysis terms can be easily addressed, so the risk rating (significance determination) should not be the only determination of whether action is taken.

**For more information**, refer to:


Mahmoudi, H. et al. 2013 A framework for combining Social Impact Assessment and Risk Assessment. *Environmental Impact Assessment Review* 43, 1-8. **http://dx.doi.org/10.1016/j.eiar.2013.05.003**

Maxwell, S. et al. 2012 *Social Impacts and Wellbeing: Multi-criteria analysis techniques for integrating nonmonetary evidence in valuation and appraisal.* London: Defra **https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69481/pb13695-paper5-socialimpacts-wellbeing.pdf**

Rowan, M. 2009 Refining the attribution of significance in social impact assessment. *Impact Assessment & Project Appraisal* 27(3), 185-191. **http://dx.doi.org/10.3152/146155109X467588**

UK Department for Communities and Local Government 2009 Multi-Criteria Analysis: A Manual. **http://www.communities.gov.uk/publications/corporate/multicriteriaanalysismanual**

### Task 14: Actively contribute to the design and evaluation of project alternatives including no go and other options.

The SIA practitioner should discuss all potential project alternatives with the affected communities, including the 'no go' option. To ensure that the positive and negative impacts of each alternative are discussed and understood by communities, the SIA practitioner may need to provide some guidance. Ideally, communities should be encouraged to contribute their own project alternatives and suggestions. Communities may not always understand the technicalities of a project, and the SIA practitioner or other project staff may need to explain this in a non-technical manner to ensure communities can make informed decisions. Visual aids such as maps, pictures and models can be used to explain different alternatives.

Where the SIA has identified that the project will cause serious harm to a community which cannot be mitigated or will lead to community conflict, they have a duty of care to inform the project proponent and request that the project's feasibility be re-assessed and/or the project be redesigned or cancelled.

# PHASE 3: DEVELOP AND IMPLEMENT STRATEGIES

## Task 15: Identify ways of addressing potential negative impacts (by using the mitigation hierarchy).

| | |
|---|---|
| **1. Avoid** | • Making changes to the project or plan (or potential location) to avoid adverse effects. This is the most acceptable form of mitigation. |
| **2. Reduce** | • Where avoidance is not possible, adverse effects can be reduced during design, construction or decommissioning. |
| **3. Repair** | • Where adverse effects cannot be reduced further, measures can be introduced to limit their influence by restoring, rehabilitating or remediating the affected environment. |
| **4. Compensate in kind** | • Where new benefits are not possible, and there are still residual impacts, it may be appropriate to provide compensatory measures that attempt to offset the adverse effect with a comparable positive one. |
| **5. Compensate by other means** | • Where compensate in kind is not possible then, as a last resource, attempt can be made to compensate by other means. |

**Figure 12: Mountain livestock herder**

**Source:** modified from João, E., Vanclay, F. & den Broeder, L. 2011 Emphasising enhancement in all forms of impact assessment. *Impact Assessment & Project Appraisal* 29(3), 170-180. **http://dx.doi.org/10.3152/146155111X12959673796326**

There are different forms mitigation can take (see Figure 12). Many social impacts can be mitigated by design. Reducing the height of a dam wall, for example, will reduce the area flooded which may mean that the number of people displaced will be reduced. Relocation and displacement are perhaps the cause of the most severe social impacts. Deciding to proceed with a series of small dams, rather than a single large dam, can considerably reduce impacts. The precise location of the siting of a dam, a bridge, or the routing of a road, railway line, pipeline or power lines can be very important in terms of the extent of social impacts created or mitigated. A few hundred metres can result in a huge difference to vibration and noise levels, as well as to aesthetics. Changing the height of the dam wall by ten or so metres can make a huge difference to the area inundated.

Participation can also be conceived as a mitigation strategy that can prevent or reduce negative social impacts. It leads to an awareness of a planned intervention, and therefore a loss of fear or uncertainty. When people feel that they have been involved, they are likely to accept some of the social impacts because they accept that the intervention is necessary for the common good. But not to consult them about issues that will affect their lives will cause anger and resentment. Sometimes, when there has been a history of change or uncertainty, people may be angry. Participatory processes will then tap into this hostility while people vent their anger. In these circumstances, the participatory process needs to allow this anger to be vented, and then to rebuild the relationship with the community to go beyond the expression of anger. This, of course, takes time. Not to go through that process potentially increases the social impacts because of the realisation of this anger. Impacts can be avoided by anticipation of potential conflict, and by preparedness for dispute management. Sometimes a degree of negotiation and trade-off is necessary. When successful participation processes are in place, these negotiated outcomes will be adhered to. Obviously, it is important that companies and project staff do not renege on agreements. This requires a degree of monitoring of project staff to ensure compliance with set standards for practice, such as hours of operation, noise levels, and non-interaction with locals where applicable.

Good processes reduce impacts, both participatory processes and also institutional processes. Clear lines of responsibility and good information flows facilitate the process. Most important to the success of the SIA process, however, is guaranteed independence of the SIA team so that they can report without fear of repercussions. Only then will all impacts be identified, and potentially mitigated.

There are many design features of a project that can be considered that might reduce impacts. Normally, maximising the employment of local people reduces impacts and maximises benefits. This should be facilitated by providing training programs so that local people can be employed even where they might not otherwise have the required skills. In some cases, the best mitigation strategy may differ depending on the context. For example, when there is an imported workforce that will be substantially culturally different than the local community, it might be better to maintain separation between locals and newcomers, while in other cases, integration is usually preferable.

### Task 16: Develop and implement ways of enhancing benefits and project-related opportunities.

Communities don't want only harm minimisation, they want to benefit from projects. No matter how well-designed projects are, there will nearly always be residual impacts on people, who will also experience changes in their lives and in their communities, especially in terms of their sense of place. Therefore, for companies to earn their social licence to operate, as well as ensuring that the livelihoods of any economically or physically displaced persons will be fully restored and preferably enhanced, they will need to provide a range of additional benefits to local communities. There are six types of ways by which a company can contribute to local communities: social investment funding; local content (local employment and local procurement opportunities); shared infrastructure; capacity building; facilitating or supporting community initiatives; and in certain circumstances the payment of royalties or levies to local authorities and/or local landowners. Note that taxes are not included here because they are usually paid to the national government and they are a normal requirement of company operation rather than being an additional benefit. Ideally all projects should undertake a mix of activities across these six types.

In many industries (notably mining), there is an industry convention that there should be a percentage of profit made available to local communities in the form of strategic social investment and as part of the project contributing to shared value and maintaining a social licence to operate. One mine in an African country, for example, has pledged $1 per ounce of gold produced plus 1% of pre-tax profit. To be regarded as social investment, this money must be in addition to any royalties or compensation to which the local community may be entitled. Social investment contributions can be in the form of: contributions to a community-managed social investment fund; investment in community infrastructure such as schools, hospitals, etc; and/or in the provision of credit (especially microfinance) to enable local people to borrow money, perhaps to establish businesses so that they can be suppliers to the project. Of the monies paid to a social investment fund, the managing committee of that fund may decide to spend those funds immediately (e.g. on community infrastructure), or may decide to invest it for the future. There are many issues with social investment funding, including: who are the beneficiaries; who decides what the money is used for; how investments decisions are made; and what the governance arrangements are. Care needs to be taken to ensure that the social investment funding does not exacerbate existing inequalities, is not a source of conflict in the community, and that the money is spent wisely and sustainably rather than on short-term ingratiation.

Local content refers to a company taking specific measures to enhance the amount of economic benefit that is experienced locally. It includes ensuring that jobs are available to people from the local community as well as making arrangements to ensure that local businesses (SMEs) can be suppliers of goods and services to the project. Thus, local procurement refers to ensuring that local firms are not artificially excluded from supplying the project by lack of visibility on opportunities and onerous tendering specifications, and to the project having capacity building arrangements to assist local firms to meet any necessary requirements.

Shared infrastructure refers to any actions that can be taken at the project site and with ancillary activities to enhance the benefits experienced by the local population. Whereas a project modification to reduce a negative impact is a mitigation measure, projects can also be modified to enhance benefits. Enhancement can take on many forms but typically is about how infrastructure used for the project might also be made available to assist nearby affected communities. There are many ways in which project infrastructure can also benefit local communities. Water treatment plants, electricity generation plants and other utilities that are built to supply the project can also be used to supply nearby local communities. Roads and bridges that are built for the project can also be used by local communities. Project enhancement may imply that some additional spend is required.



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Capacity building refers to establishing training programs and facilitation processes that can build the skills of local people. This can help them get jobs in the project or to supply goods and services to the project. However it can also be to enhance the capacity of people generally and to supply goods and services for the whole community. It might be to train staff so that they have a range of skills which they can use when the project finishes. Sometimes workers employed on short-term contracts for the construction phase of a project are disappointed and annoyed when their employment is terminated at the end of the construction phase, especially when they may see other people keep their jobs. Their concern is legitimate, especially if their previous livelihoods are no longer possible. In such a situation, the company should assist the affected individuals to develop skills to assist in their post-construction employment options. Where the communities have been victims of conflict or a natural disaster, facilitating post-traumatic stress disorder counselling or post conflict management courses will be desirable. The actions of the company need to be done in close discussion with the local community so that they are wanted by the local community and that the company is not seen as patronising or parochial.

**For more information,** refer to:

ICMM 2012 *Community Development Toolkit* **http://www.icmm.com/community-development-toolkit**

Rowan, M. & Streather, T. 2011 Converting project risks to development opportunities through SIA enhancement measures: A practitioner perspective. *Impact Assessment & Project Appraisal* 29(3), 217-230. **http://dx.doi.org/10.3152/146155111X12959673796164**

## Task 17: Develop strategies to support communities in coping with change.

At all times, an awareness of the significance of social issues, and a sensitivity to them is required. This is necessary not only by SIA staff, but also by the EIA team and project staff. It goes without saying that the SIA should only be undertaken by appropriately qualified social specialists (anthropologists, community psychologists, geographers, sociologists, social workers, health practitioners, etc) who have training in SIA. Sometimes spiritual or religious impacts may be severe, but such topics may be taboo or sensitive matters to talk about, especially with strangers. Here, developing the confidence of community leaders (the village priest, medical practitioner or other local professional or dignitary) can be important. In dam projects, for example, while resettlement of people has many social impacts, greater concern can exist about deceased ancestors and their graves. If cemeteries are to be relocated and bodies re-interred, considerable distress can be caused to villagers during this process. This situation needs to be dealt with sensitively and in negotiation with local people. The active creation of rituals or festivals to remember the past, and to celebrate the new, is desirable. Rituals and festivals are important social processes that allow people to deal with issues that affect their lives. Supporting the creation and holding of such festivals by local communities is one of the coping strategies that can be developed to assist in the change management process.

**For more information**, refer to:

Magis, K. 2010 Community resilience: An indicator of social sustainability. *Society & Natural Resources* 23(5), 401-416. **http://dx.doi.org/10.1080/08941920903305674**

Maclean, K., Cuthill, M. & Ross, H. 2013 Six attributes of social resilience. *Journal of Environmental Planning and Management* 57(1), 144-156. **http://dx.doi.org/10.1080/09640568.2013.763774**



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## Task 18: Develop and implement appropriate feedback and grievance mechanisms.

Good practice in social performance and SIA always required the implementation of feedback mechanisms to enable stakeholders to provide input to the SIA and raise their concerns about the project. Participatory processes are critical to effective SIA and are used in almost all SIA steps (see Task 6 and earlier sections of this document). However, having a formal grievance mechanism provides an additional back-up procedure to ensure that rights-holders have access to remedy. Apart from signalling that the project is compliant with its human rights responsibilities, a genuine commitment to the proper functioning of grievance mechanisms will build trust, maintain and grow the project's social licence to operate, reduce harm in the community, and reduce business risk.

Ideally, projects should have a culture of openness and accessibility. Community liaison staff should have a good relationship with project-affected communities, and people should be able to easily raise their concerns. However, no matter how accessible a liaison officer might think they are, there can always be some members of local communities who feel that they do not have access, or that they were not being taken seriously. For this reason, it is important that there be a variety of feedback mechanisms in place, and that formal grievance mechanisms are established from early in the life of the project. Different grievance mechanisms may be needed for different stakeholder groups, particularly for workers and for impacted communities.

Although a good idea and arguably should have been a stronger part of social performance practice in the past, grievance mechanisms have attracted considerable attention particularly since the passing of the United Nations Guiding Principles on Business and Human Rights in 2011. The third pillar in the 'protect, respect and remedy' framework is that people must have adequate access to remedy. In fact, access to remedy is considered to be a human right in itself. The UNGP encourages the use of non-judicial means of dispute resolution, but also requires that judicial means are available.

A community grievance mechanism (CGM) can be considered to be a locally-based, formalized way to accept, assess, and address complaints from members of nearby communities concerning the performance or behaviour of the project/company, its contractors and employees. A 'grievance' is defined by the UNGP as "a perceived injustice evoking an individual's or a group's sense of entitlement, which may be based on law, contract, explicit or implicit promises, customary practice, or general notions of fairness of aggrieved communities". In effect, a grievance is any perceived or actual issue, concern, problem, or claim that an individual or community group wants a company or contractor to resolve.

Sometimes a distinction is made between concerns or issues, and grievances. Concerns or issues are less significant matters such as questions, requests for information, or general perceptions that may or may not be related to a specific impact or incident. If not addressed to the satisfaction of the person or group lodging it, concerns may well become complaints, and will lead to a loss in the project's social licence to operate. Concerns do not have to be registered as formal complaints, however they should be noted in an appropriate management system so that emerging trends can be identified and addressed through community engagement before they escalate. Complaints or grievances refer to allegations of specific incidents and of any damage, impact or dissatisfaction resulting from company or contractor actions, whether perceived or actual.

Grievance mechanisms typically follow the steps indicated in Figure 13. For the mechanism to work effectively, the procedure must be known to the potential complainants, and the process must be regarded as being legitimate to them. Principle 31 of the UNGP identified several criteria that apply to grievance mechanisms (see Box 10).

Over time, there should be some assessment of how effective the grievance procedure was. Not having any grievances is generally a bad sign because it is more likely to mean that the community had no faith that lodging a grievance would lead to any action, or that they did not know such a procedure existed, than meaning that the project was free of any concerns. All projects will generally create some concerns and it would be better to see how a project dealt with concerns than pretend it did not have any. Looking at the clear-up rate and the how satisfied complainants were with the procedure would be a better indicator of the effectiveness of the mechanism.

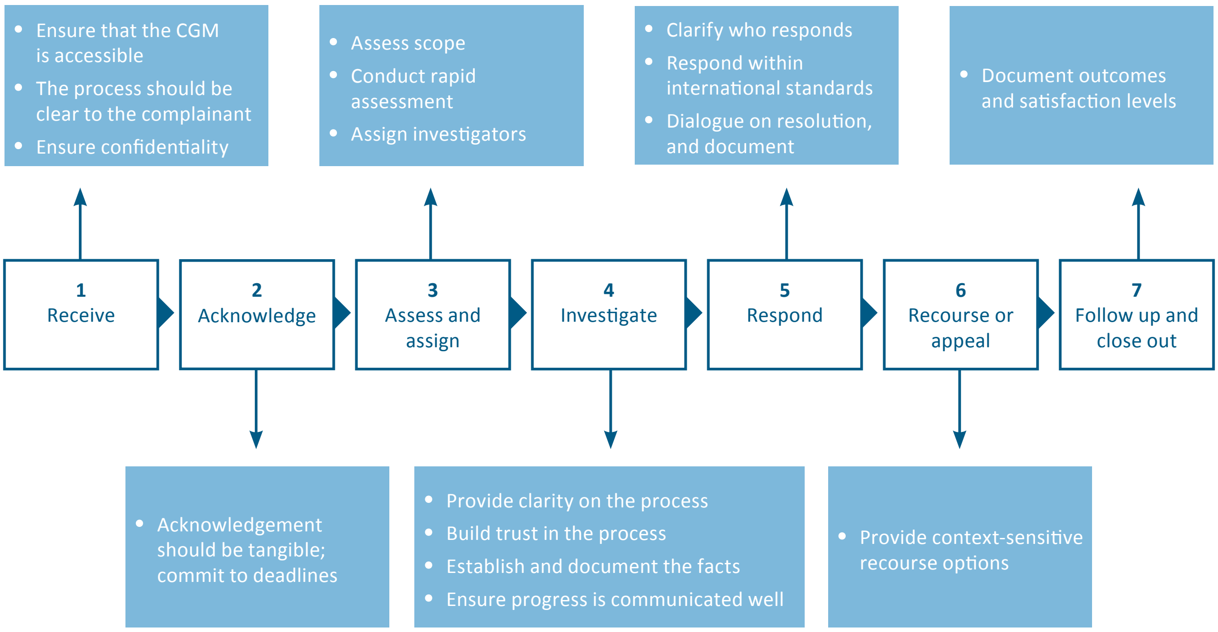


**Figure 13: Steps in processing a grievance**

**Source:** IPIECA 2015 *Community Grievance Mechanisms in the Oil and Gas Industry. A Manual for implementing operational-level Grievance Mechanisms and designing Corporate Frameworks* **http://www.ipieca.org/sites/default/files/publications/Community_grievance_mechanisms_manual_2015.pdf** (used with permission).

## BOX 10: Effectiveness criteria for non-judicial grievance mechanism

(a) Legitimate: enabling trust from the stakeholder groups for whose use they are intended, and being accountable for the fair conduct of grievance processes;

(b) Accessible: being known to all stakeholder groups for whose use they are intended, and providing adequate assistance for those who may face particular barriers to access;

(c) Predictable: providing a clear and known procedure with an indicative time frame for each stage, and clarity on the types of process and outcome available and means of monitoring implementation;

(d) Equitable: seeking to ensure that aggrieved parties have reasonable access to sources of information, advice and expertise necessary to engage in a grievance process on fair, informed and respectful terms;

(e) Transparent: keeping parties to a grievance informed about its progress, and providing sufficient information about the mechanism's performance to build confidence in its effectiveness and meet any public interest at stake;

(f) Rights-compatible: ensuring that outcomes and remedies accord with internationally recognized human rights;

(g) A source of continuous learning: drawing on relevant measures to identify lessons for improving the mechanism and preventing future grievances and harms;

Operational-level mechanisms should also be:

(h) Based on engagement and dialogue: consulting the stakeholder groups for whose use they are intended on their design and performance, and focusing on dialogue as the means to address and resolve grievances.

**Source:** Principle 31 in United Nations 2011 *Guiding Principles on Business and Human Rights.* **http://www.ohchr.org/Documents/Publications/GuidingPrinciplesBusinessHR_EN.pdf**



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**For more information**, refer to:

IFC 2009 *Good Practice Note: Addressing Grievances from Project-Affected Communities*. Washington: IFC. **http://www.ifc.org/wps/wcm/connect/cbe7b18048855348ae6cfe6a6515bb18/IFC%2BGrievance%2BMechanisms.pdf?MOD=AJPERES&CACHEID=cbe7b18048855348ae6cfe6a6515bb18**

IPIECA 2015 *Community Grievance Mechanisms in the Oil and Gas Industry. A Manual for implementing operational-level Grievance Mechanisms and designing Corporate Frameworks* **http://www.ipieca.org/sites/default/files/publications/Community_grievance_mechanisms_manual_2015.pdf**

Office of the Compliance Advisor/Ombudsman 2008. *A Guide to Designing and Implementing Grievance Mechanisms for Development Projects*. Washington, DC: IFC. **http://www.cao-ombudsman.org/howwework/advisor/documents/implemgrieveng.pdf**

Rees, C. 2008 *Rights-Compatible Grievance Mechanisms: A Guidance Tool for Companies and Their Stakeholders*. Corporate Social Responsibility Initiative, John F. Kennedy School of Government, Harvard University, Cambridge, MA. **http://www.reports-and-materials.org/Grievance-mechanisms-principles-Jan-2008.pdf**

World Bank 2012 *Feedback Matters: Designing Effective Grievance Redress Mechanisms for Bank-Financed Projects, Part 1. The Theory of Grievance Redress*. **http://hdl.handle.net/10986/12524**

World Bank 2012 *Feedback Matters: Designing Effective Grievance Redress Mechanisms for Bank-Financed Projects, Part 2. The Practice of Grievance Redress*. **http://hdl.handle.net/10986/18364**

## Task 19: Facilitate an agreement-making process between the communities and the developer leading to the drafting of an Impacts & Benefits Agreement (IBA).

Particularly in large projects with significant impacts, a good way to record understanding of what is promised by a project and for a community to hold the company to these promises into the future is by the drafting and eventually signing of an Impacts & Benefits Agreement (IBA). Depending on the specific context, these agreements go by a range of names, including: Community-Based Agreements, Community Development Agreements, Benefit Sharing Agreements, Partnering Agreements, Indigenous Land Use Agreements, Empowerment Agreements, Community Contracts, Shared Responsibility Agreements, and Good Neighbour Charters. However, Impacts & Benefits Agreements seems to be the most appropriate term as it is the most apt description of what it is. The SIA practitioner, in their role as a link between the communities and the developer, can play a key role in the development of an IBA to ensure that the IBA is not just something agreed to at the time of signing, but is something that remains a valued and valuable document for the life of the project. To do this, it needs to address the issues that are likely to be concerns into the future.

IBAs are negotiated agreements between communities and companies, and sometimes including governments. Historically IBAs tended to be used only with Indigenous communities and as a way of recording and evidencing the free, prior and informed consent (FPIC) of the impacted communities. An IBA is, in effect, a negotiated legal contract in which community representatives provide documented support of a project in exchange for specific benefits such as royalties and other direct payments, employment opportunities and promised social investment contributions. The IBA also records any specific conditions the local community may have (e.g. relating to protected areas, sacred sites, etc). IBAs are potentially a valuable tool for addressing issues between any project-affected community and the project/company, and arguably should be used for all projects.

IBAs should address all issues relevant to a community's determination of whether they would give their broad-based approval or informed consent (FPIC) to a project, including: all financial payments; employment and contracting requirements, including statements about the project's commitment to local content; environmental, social and cultural impact management plans and mitigation activities; capacity building plans; governance arrangements and grievance mechanisms; and any agreements related to specific things of concern to the local community. The process of negotiating the IBA is as important as the outcome, as it helps build effective relationships and establishes trust and respect.

There is an evident power imbalance between the company and affected communities. Irrespective of whether a community would sign the agreement or not, the company must ensure it is not causing unreasonable social impacts, and that it is not abusing the human rights of people in the group. To safeguard itself from future litigation or protest action (i.e. non-technical risk), the company must ensure that it fully discloses all relevant information and that the community has fully understood what the issues will be. It is therefore necessary that the community has sufficient time to consider the issues and is provided with appropriate financial resources to enable them to get independent professional advice and legal support. No agreement could be deemed to have been made in good faith if the local community did not have competent independent professional advice.

Although it is for each community to determine their own culturally-appropriate way of establishing the community's position, the project staff should ensure that the division of benefits within the community is fair, and that there is broad-based consent in the community. Situations in which there was a signed agreement but not broad support may be indicative of problems later on.

**For more information**, refer to:

Gibson, G. & O'Faircheallaigh, C. 2010 *IBA Community Toolkit: Negotiation and Implementation of Impact and Benefit Agreements*. Walter & Duncan Gordon Foundation: Ottawa **http://www.ibacommunitytoolkit.ca**

Keenan, J. & Kemp, D. 2014 *Mining and Local-Level Development: Examining the Gender Dimensions of Agreements between Companies and Communities*. Brisbane, Australia: Centre for Social Responsibility in Mining, The University of Queensland. **https://www.csrm.uq.edu.au/publications?task=download&file=pub_link&id=805**

Nish, S. & Bice, S. 2011 "Community-based agreement making with land-connected peoples", in Vanclay, F. & Esteves, A.M. (eds) *New Directions in Social Impact Assessment: Conceptual and Methodological Advances.* Cheltenham: Edward Elgar, pp.59-77.

O'Faircheallaigh, C. 2011 "SIA and Indigenous social development", in Vanclay, F. & Esteves, A.M. (eds) *New Directions in Social Impact Assessment: Conceptual and Methodological Advances*. Cheltenham: Edward Elgar, pp.138-153.

### Task 20: Assist the proponent in facilitating stakeholder input and drafting a Social Impact Management Plan (SIMP) which puts into operation the benefits, mitigation measures, monitoring arrangements and governance arrangements that were agreed to in the IBA, as well as plans for dealing with any ongoing unanticipated issues as they may arise.

Social Impact Management Plans (SIMPs) are intended to be a tool by which a regulator can assess the extent to which a proponent is competent at identifying and, more importantly, addressing social impacts. It therefore primarily considers how the company intends to implement social impact management actions into company operations. SIMPs are increasingly being requested by regulators in preference to conventional statements of impacts, thus demonstrating the shift in SIA to a focus on the management of social impacts (rather than simple prediction of impacts). SIMPs clarify the roles and responsibilities of proponents, governments, communities and other stakeholders in the mitigation, monitoring and ongoing management of social impacts and opportunities throughout the project lifecycle. SIMPs also provide an opportunity to link project activities with local and regional planning. The aspects related to impact management agreed in the IBA must be included in the SIMP.

A SIMP is usually translated in various operational management plans that guide company implementation (see Tasks 21 & 22). To develop a SIMP that is realistic and implementable, input and buy-in from a number of actors such as communities, the proponent, government and other stakeholders is needed. For example, conducting awareness campaigns for artisanal fishers to avoid an exclusion zone needs to be designed with the input of the local fisheries association. Ensuring enough time for the necessary negotiations to achieve agreement needs time. The SIA practitioner assists the respective actors in considering the elements to be included in the SIMP and how they will be addressed.

It is important to realise that no matter how good the SIA process might be, there will always be some unintended and unanticipated impacts that arise. An important aspect of the SIMP is to ensure that there will be an ongoing social monitoring and adaptive management program included in the project.

**For more information**, refer to:

Franks, D. et al. 2009 *Leading Practice Strategies for Addressing the Social Impacts of Resource Developments*. St Lucia: Centre for Social Responsibility in Mining, **http://www.csrm.uq.edu.au/docs/Franks_etal_LeadingPracticeSocialImpacts_2009.pdf**

Franks, D. & Vanclay, F. 2013 Social Impact Management Plans: Innovation in corporate and public policy. *Environmental Impact Assessment Review* 43, 40-48. **http://dx.doi.org/10.1016/j.eiar.2013.05.004**

Queensland Government 2010 *Social Impact Assessment: Guideline to preparing a Social Impact Management Plan*. **http://www.dsdip.qld.gov.au/resources/guideline/simp-guideline.pdf**

## Task 21: Put processes in place to enable proponents, government authorities and civil society stakeholders to implement the arrangements implied in the SIMP and IBA, and develop and embed their own respective management action plans in their own organizations, establish respective roles and responsibilities throughout the implementation of those action plans, and maintain an ongoing role in monitoring.

Although the SIMP potentially could be a company's plan for managing social impacts as well as a regulatory tool, most corporations have a range of other documents and procedures for recording and implementing their plans and actions. The internal version of the SIMP is sometimes called a Social Performance plan. It is essential that all the tasks and management actions outlined in the SIMP and IBA are registered and enacted by the appropriate actor for that task or management action. Each action needs to be clearly allocated to a responsible person/institution and implemented in their workplan. Many of the tasks will be allocated to the proponent, but some tasks may be assigned to a range of other stakeholders. It is essential that there be some monitoring of these tasks allocated to other institutions so that all social activities are undertaken as scheduled. Having a champion, especially at senior manager level, to promote the SIMP and social issues within the company is highly desirable. SIA practitioners would be well advised to identify and cultivate possible champions.

## Task 22: Assist the proponent in developing and implementing ongoing social performance plans that address contractor obligations implied in the SIMP.

Projects are rarely fully self-contained. Most large projects use contractors for a wide range of tasks and contractors are an important part of a project's operations. It is essential therefore that all agreements made by the operator (the project) are then also binding on all contractors. Putting an SIA and SIMP into action within the project involves designing and implementing a Contractor Management Plan for medium-high risk activities, which covers the client's and contractor's respective roles and responsibilities within a range of social performance activities, including:

- identifying key stakeholders, and maintaining a stakeholder list for the project
- day-to-day consultation with stakeholders, including notification of project work by the proponent or its contractors
- maintaining records of engagement activities and commitments
- developing communications materials
- designing requirements of contracting partners based on an understanding of the social impacts, prior to going into the field and while they are in the field
- defining the role of community relations officers in managing contractor performance
- maintaining a risk register by identifying all social risks related to the project work and methods to eliminate, reduce or mitigate those risks
- advising contractor managers on issues relating to cultural sensitivity and worker behaviour
- working with contractors to notify affected persons of any nuisance or disturbance as a result of the contractor's work and to mitigate impacts
- conducting training for contractors on social performance matters
- building trust and accountability with external stakeholders, e.g. through public reporting, grievance mechanism, social monitoring by third-party organisations.



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Contractor management for social performance requires designing Instructions to Tender with sufficient hooks to build social performance requirements into contracts. These can include: a Contractor Social Risks & Opportunities Assessment; conformance with a Code of Conduct; and prescribing guidelines to Contractors to develop their own social performance plans. It requires the evaluation of bids in terms of social performance, and the inclusion of key performance indicators for social performance in final bid discussions. The post-award phase is also important to inform what needs to be done before the contractor can go to the field; and to establish what actions will be taken in the event that the contractor is non-compliant. This requires setting up a social performance management system; and conducting induction and training on, for example, the code of conduct, camp rules, appropriate and inappropriate interactions with local communities, and grievance procedure. The management of issues in the field also needs defining to ensure a contractor proactively manages social issues. Some mechanisms to facilitate compliance include appointing a Contractor social performance liaison; having clearly-defined roles between the contractor and the proponent's social performance teams; and jointly agreeing on a social performance management plan. Tracking performance involves setting Key Performance Indicators (KPIs), selecting appropriate reporting mechanisms and frequency; and building incentives and punitive measures into contracts to ensure targets are met.

**For more information**, refer to:

Overseas Development Institute ca 2010 *Involving Large Contractors in enhancing Social Performance during Construction*. **http://commdev.org/files/1334_file_Involving_Large_Contractors.pdf**

Wilson, E. & Kuszewski, J. 2011 Shared Value, *Shared Responsibility: A New Approach to Managing Contracting Chains in the Oil and Gas Sector*. London: IIED. **http://pubs.iied.org/16026IIED.html**

# PHASE 4: DESIGN AND IMPLEMENT MONITORING PROGRAMS

## Task 23: Develop indicators to monitor change over time.

SIA is the process of managing the social issues that arise from the changes brought about by a project. While this is an adaptive management process, it builds on a thorough understanding of the context in which the project is being implemented, i.e. the community profile (see Task 4) and the social baseline (see Task 8). To monitor change over time, it is important to identify and track social indicators that measure all likely impacts and any issues that may be of concern to the various stakeholders. Also, it is necessary to ensure that there are appropriate indicators and monitoring processes to track groups of particular concern, such as the various vulnerable groups and other often under-considered groups including migrant workers, people living along transportation routes, those within close proximity of blasting and other significant point sources of impact generation. Having a mechanism to monitor for the unexpected is also needed. By monitoring, the effectiveness of mitigation measures can be assessed and corrective action taken if necessary. Also, where any unanticipated issues arise, they can be addressed quickly. Indicators also need to be considered to measure potential cumulative impacts.

To measure the residual impacts, the consequences of the impacts, and the success of mitigation over time, the first step is to decide what needs to be measured. Each potential impact or issue of concern needs to be operationalised by one or more indicators (variables). Indicators are usually described as having to be SMART – that is, specific to the issue under consideration, measurable and achievable in the sense that the data must be available, action-oriented in the sense that the indicator must be linked to a response mechanism if there any exceedance, relevant to the issue and perhaps reliable in the statistical sense (i.e. accurate), and time-sensitive, that is being able to quickly track changes at a meaningful scale. In addition to having SMART indicators, it is also suggested that some indicators should be SPICED – subjective in that they are based on the stakeholders' own experiences; participatory in that they are developed together with the relevant stakeholders; interpretable and communicable to other people; cross-checked and compared with other data and other contexts; empowering to all stakeholders and a positive experience in their development and implementation; and diverse and disaggregated so that the different issues of different stakeholders (especially women and vulnerable groups) are considered.

All categories of project stakeholders need to be involved in the process. They can provide input in the development of the indicators, for example by considering the issues of: whether the indicators are relevant; do they measure what they are supposed to measure; is there a better way to measure the issue based on local knowledge; is anything missing that would be important to measure but is not covered in the monitoring plan. The frequency of measurement of each social indicator needs to be appropriate to each indicator and the severity (or significance in EIA terms) of the underlying issue. Continuous measurement is desirable where that is realistic, but where this is not possible, the frequency of measurement needs to be sufficient to enable corrective action to occur in a reasonable timeframe. For some impacts, there may already exist indicators and associated data collection mechanisms that can be adequately used, however most issues will require the delineation of new indicators and the implementation of new data collection processes. Allowing time and budget to properly develop and test these indicators is essential to ensure that they will be useful in the future. Cutting costs by having inadequate pre-testing or piloting of social indicators may well lead to a longer term wastage of funds by ultimately collecting unusable data and/or failing to detect serious impacts that may emerge, and thus to business risks. Careful indicator development and monitoring therefore is an effective risk management strategy.

**For more information**, refer to:


Lennie, J. et al. 2011 *Equal Access Participatory Monitoring and Evaluation Toolkit*
**http://betterevaluation.org/toolkits/equal_access_participatory_monitoring**

Roche, C. 1999 *Impact Assessment for Development Agencies: Learning to Value Change.* Oxford UK: Oxfam.
**http://policy-practice.oxfam.org.uk/publications/impact-assessment-for-development-agencies-learning-to-value-change-122808**

Vanclay, F. 2013 The potential application of qualitative evaluation methods in European regional development: Reflections on the use of Performance Story Reporting in Australian natural resource management. *Regional Studies*
**http://dx.doi.org/10.1080/00343404.2013.837998**




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### Task 24: Develop a participatory monitoring plan.

Once the indicators have been developed (Task 23), they need to be collated into a monitoring plan. Monitoring plans need to be developed in a participatory way, and there needs to be careful consideration given to the governance and oversight of the monitoring process if it is to have legitimacy. The monitoring plan should serve as a guide to show how the impacts will be monitored over time. There must be a clear indication of what the indicators are, how they relate to the identified social issues, how each indicator is defined and operationalised, how each indicator will be measured and at what frequency. The monitoring plan must also indicate who will be responsible for actioning the measurement, how the results will be communicated, and what the course of action will be if there is an exceedance from the agreed level (benchmark).

The key stakeholders need to agree on the key monitoring issues: the method by which measurement will happen, frequency of monitoring, responsible people, and most important, on the way that the results will be reported to all stakeholders.

The monitoring plan should be a dynamic, working document, and should be reviewed on a regular basis to determine whether all the indicators are still relevant, whether the methods of measurement remain appropriate (especially in the context of technological advances), and whether any new issues have emerged that should be included in the monitoring plan. Stakeholder participation is vital for the monitoring plan to be executed successfully and for it to have legitimacy with stakeholders. Not having stakeholder participation could result in the plan being viewed as part of a tick-box approach and would reduce the project's social licence to operate.

The monitoring plan should measure impacts in such a way that it is actionable. If the monitoring results indicate that action is required for the management of an impact, it must be known where and how an intervention can take place to address the issue. Being aware of what the stakeholders would require in order for them to be satisfied with the intervention is important if a company wants to maintain and grow its social licence to operate. The procedure to address negative results should be in place from the beginning of the project to ensure that action can be taken quickly and efficiently and that sufficient budget is available to allow this to happen. In order to maintain social license to operate and legitimacy with the stakeholders in the event of an incident, fast and efficient action is of the essence.

**For more information**, refer to:

Office of the Compliance Advisor/Ombudsman 2008 *Participatory Water Monitoring: A Guide for Preventing and Managing Conflict*. Advisory note, Washington, DC: IFC.
**http://www.cao-ombudsman.org/howwework/advisor/documents/watermoneng.pdf**

IFC 2010 *International Lessons of Experience and Best Practice in Participatory Monitoring in Extractive Industry Projects.*
**http://commdev.org/international-lessons-experience-and-best-practice-participatory-monitoring-extractive-industry**

World Bank 2013 ***How-To Notes.*** *Participatory and Third Party Monitoring in World Bank-Financed Projects: What can Non-State Actors do?* **http://siteresources.worldbank.org/EXTSOCIALDEVELOPMENT/Resources/244362-1193949504055/4348035-1352736698664/8931746-1364579999657/HowToNotesParticipatory&TPM.pdf**

### Task 25: Consider how adaptive management will be implemented and consider implementing a social management system.

The social environment is constantly changing and adapts to these changes. It is therefore important to be flexible when considering the management and monitoring of social impacts. Adaptive management is innate to social impact management. This underlines the importance of monitoring and regular feedback of the results. Information received from monitoring should be used to update the SIMP or social performance plan. These plans need to be living documents and should be reviewed and updated regularly (perhaps yearly). It is important to involve all stakeholders in the adaptive management process. Processes that were put in place to implement the SIMP or IBA can be used to inform the adaptive management process. This includes stakeholder meetings where one can reflect on positive and negative impacts and plan for better outcomes in the future based on lessons learned in current processes.

It is very evident that for each project there will be a vast amount of social performance/SIA activities that need to be completed, monitored, tracked, reported-on, etc. The extent of the activities discussed in this guidance note imply that keeping track of all these things will be difficult, especially if there should ever be change in social performance personnel. The implementation of a social management system (SMS) somewhat akin to an environmental management system (EMS), or perhaps integrated with it to form a Social and Environmental Management System (SEMS), should be considered.

**For more information**, refer to:

Endter-Wada, J. et al. 1998 A framework for understanding social science contributions to ecosystem management. *Ecological Applications* 8(3), 891-904. **http://dx.doi.org/10.1890/1051-0761(1998)008%5B0891%3AAFFUSS%5D2.0.CO%3B2**

IFC 2014 *Environmental and Social Management System Implementation Handbook: Construction*. Washington DC: International Finance Corporation. **http://www.ifc.org/wps/wcm/connect/c03aa6804493c5bba71aafc66d9c728b/ESMS+Handbook+Construction.pdf**

### Task 26: Undertake evaluation and periodic review (audit).

The monitoring of social impacts, the adaptive management of social issues, the addressing of grievances, and finding opportunities to create benefits for local communities must continue throughout the life of a project. In that sense, the social performance work of a project is ongoing. The generalist SIA practitioner, however, is likely to be involved only up until all initial issues have been addressed and most of the ongoing systems are in place – thus, typically sometime after the end of the construction phase and after commencement of the operational phase of the project. At this point, it is desirable to undertake an evaluation of how well the SIA was done. Lots can be learnt from assessing what worked and what did not work so well with the way each SIA task was undertaken. Although the monitoring and adaptive management processes deal with any issues or social impacts not considered in the SIA or that otherwise arise, the intention in this task is to have a review to reflect on and improve the overall SIA process for this project, as well as to consolidate learnings for the practitioner, the company and, where learnings are shared, to improve the SIA profession as a whole. This will help to improve the processes of predicting social impacts and in fine-tuning mitigation and enhancement measures.

In addition to an evaluation of the SIA at completion of the SIA, each project should be periodically reviewed. While the adaptive management process should continue to address any issues that arise, an audit is needed to establish that that is indeed the case – that the adaptive management process is working. An audit can also determine whether there are significant departures from any targets for residual impacts and/or whether any cumulative impacts are being experienced.

Because some large projects have a life expectancy of many years, a periodic audit is appropriate to ensure that the project remains up to current international good practice. Good and best practice changes over time, and unless a project continues to innovate, what was once good or best practice can very soon become dated. The experience in many of the examples in this document and elsewhere frequently reveal stories where despite best intention, negative outcomes resulted from poor planning and other inadequacies. Periodic audit (say every 3 to 5 years) is appropriate.

While projects or project owners (corporate headquarters) may require internal audits, other stakeholders can also demand audits, perhaps on a more frequent basis, or on an ad hoc basis. Many stakeholders can exert power over a project. For example, a grievance that was not satisfactorily dealt with through the community grievance mechanism (see Task 18) might escalate when the community brings their complaint to the financiers backing the project. Where the IFC is involved, complaints can be lodged with the Compliance Advisor Ombudsman (CAO) (**http://www.cao-ombudsman.org**). Each year, some 40 odd complaints are received, of which around 15 are deemed to be eligible for consideration by the CAO. Although it is the right of people to bring such action and many of the complaints reveal major problems with projects, a complaint does create a lot of additional work for the company staff and attracts much negative attention. Even if the complaint is not upheld, there can still be residual reputational harm to the company. Taking every effort to avoid complaints, for example by having regular internal audits, would be an appropriate precautionary measure.

Over the last decade or so, there has been a major rise in ethical investing, that is, investment decision making that considers environmental and social factors in the selection of investments. Increasingly, many of the large pension funds and institutional investors are shifting to ethical investment. While this typically affect new investment decisions, it can also lead to a review of existing investments and a demand that publicly-listed companies meet ethical investment standards. There are cases where this has led to audits (due diligence assessments) of projects to determine the extent to which they were consistent with human rights and social performance expectations, with the threat of the pension fund reconsidering its investment decisions if there would be an unfavourable verdict. Such a disinvestment would have had major ramifications for the company. Into the future, it is likely that there will be considerable work for SIA consultants conducting such audits and due diligence assessments.

Most companies subscribe to the notion of continuous improvement and the Plan, Do, Check, Act cycle. Regular audits therefore are a normal part of responsible business management. Environmental management system accreditation processes (e.g. ISO 14001), the standards of the Global Reporting Initiative, and many other corporate management philosophies and procedures all expect periodic audits.

**For more information**, refer to:


Aim for Human Rights 2009 *Guide to Human Rights Impact Assessment Tools*
**http://www.humanrightsimpact.org/fileadmin/hria_resources/Business_centre/HRB_Booklet_2009.pdf**

International Business Leaders Forum & IFC 2011 *Guide to Human Rights Impact Assessment and Management* (HRIAM). **http://www.ifc.org/hriam**

Kemp, D. & Vanclay, F. 2013 Human rights and impact assessment: clarifying the connections in practice. Impact Assessment & Project Appraisal 31(2), 86-96. **http://dx.doi.org/10.1080/14615517.2013.782978**

Morrison-Saunders, A., Marshall, R. & Arts, J. 2001 EIA follow-up: Best practice principles.
**http://www.iaia.org/publicdocuments/special-publications/SP6.pdf**

Storey, K. & Jones, P. 2003 Social impact assessment, impact management and follow-up: A case study of the construction of the Hibernia offshore platform. *Impact Assessment & Project Appraisal* 21(2), 99-107.
**http://dx.doi.org/10.3152/147154603781766400**

World Bank 2013 *Human Rights Impact Assessments: A Review of the Literature, Differences with other forms of Assessments and Relevance for Development.*
**http://siteresources.worldbank.org/PROJECTS/Resources/40940-1331068268558/HRIA_Web.pdf**

## Typical contents listing of a Social Impact Assessment report and/or a Social Impact Management Plan

A typical Social Impact Assessment report or Social Impact Management Plan document (intended for an external audience) is likely to include the items listed below. The precise listing of chapters and what order they appear will depend on the particular circumstances of each case and the expectations of the intended audience for the report. There may also be specific requirements in the particular jurisdiction of the case that need to be considered.
The order of items is not fixed and some elements perhaps could be presented as separate reports or as appendices rather than being in the main report. Practitioners must make efforts to ensure that the SIA or SIMP report becomes an effective decision making and management tool, by being understandable to non-social practitioners and the public, includes only relevant information, and has clear mitigation measures.

| Chapter Title | Description of contents of chapter |
|---|---|
| Cover | |
| Inside Front Cover | Publication statement indicating the authors (i.e. names of the individuals responsible for doing the work and writing the report), publisher, date of publication and other information to establish the nature and purpose of the document. |
| Executive Summary | A short statement of key issues and findings. |
| Expert Review Statement | A letter/report from any expert or peer reviewer (or perhaps a joint statement if there was a number of reviewers) to indicate how the review was conducted, what constraints applied to the reviewers, and any comments, concerns and recommendations of the reviewers. A response from the authors to the review might also be appropriate. |
| Introduction | A general introduction to the report making the purpose of the report clear, perhaps including a short general statement about how the document connects to SIA literature/philosophy. |
| Project Summary | A good description of the project and all ancillary activities so that readers can get a sense of the project. Where project alternatives or options exist, they could be explained here. |
| Methodology | A statement about the overall design of the SIA, what methods were used, what community engagement processes were used, and how ethical issues were considered and addressed. Perhaps definitions and/or a discussion of key concepts. Some link to the SIA and social research literature would be expected here. A discussion of the governance arrangements for the conduct of the SIA should be provided. Importantly, the limitations of the applied methodology would also be included, including decisions to narrow or expand the scope over the course of the SIA. |
| Applicable Legal Framework and Standards | A discussion of the legal framework(s) and applicable legislation, regulations and guidelines that apply to the particular case. This would include not only local legislation/regulation, relevant institutions and their responsibility towards the project, but also mention of international standards, such as the IFC Performance Standards, guidance from international industry organisations, and reference to this SIA guidance document. |
| Community Profile and Social Baseline | If an extended community profile and social baseline are to be included as appendices, then at least include a summary of key characteristics and key stakeholder groups here; alternatively include the community profile and baseline data here. Key historical issues should also be discussed. Key aspects of the physical environment that may be relevant to understanding the context should be included too. |



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|---|---|
| Scoping Report | A statement of all potential social impacts considered in the assessment phase. The disposition of each impact considered should be made clear. Where this is presented as a separate report, a summary should be provided. Alternatively, this can be an appendix. |
| Prioritized Listing of Key Social Impacts | This is a listing of the residual impacts with a discussion of how different stakeholders are affected. There should be a particular focus on Indigenous peoples, women and vulnerable groups. |
| Resettlement (Summary) | If resettlement is required, or if physical or economic displacement will occur, a short description of how the resettlement process will be undertaken, what compensation will be provided and how it will be determined, and what measures will be taken to restore and enhance livelihoods. A fully-developed Resettlement Action Plan will be required as a separate document. |
| Summary of Mitigation and Management Measures | A list of mitigation and other management measures to address social issues should be provided. There should be a costing and timeframe for implementation for proposed mitigation measures. |
| Monitoring Plan and Contingency Plan (Adaptive Management) | A plan for how monitoring will be undertaken – what will be monitored, how monitored, how often and who is responsible, as well as how the company will respond should an allowance threshold be exceeded – needs to be provided. |
| Benefit Statement | This is a statement of the likely project benefits to the local communities, including of all proposed social investment actions, and local content and local procurement strategies. |
| Ongoing Community Engagement Strategy and Grievance Mechanisms | A description of the intended ongoing community engagement processes. Also a description of what grievance mechanisms will be provided and what processes will be used for managing grievances. |
| Governance Arrangements | A discussion of the governance arrangements that will apply to the ongoing community engagement processes, the grievance mechanisms, the monitoring process, and to ensure the ongoing acceptability of the social investment program. |
| References | A list of all references used in the report, and any key references that informed the design of the SIA research. |
| Appendices | The appendices that are to be included will vary from project to project and will be affected by what is included in the body of the report but may include: questionnaires, interview schedules, consent form templates, an extended community profile, baseline data; a scoping report (i.e. a listing of all issues considered as possible social impacts). |



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# Review Criteria for checking Social Impact Assessment Reports and Social Impact Management Plans

SIA processes ideally involve continuous reporting back to the various stakeholders including the affected communities and the project management. Information arising through the SIA might be used long before the SIA is actually completed. Because of this continuous reporting, SIA should be seen as a process not as a product. Nevertheless, a final report will normally be required as a way of documenting methodology, procedures, and findings. Traditionally, a statement of social impacts equivalent to an Environmental Impact Statement was produced, and often an SIA would be a component of an EIA/EIS. Best practice in SIA, however, is to provide a Social Impact Management Plan (SIMP), which more than just lists likely impacts, it emphasises how the impacts will be managed, what mitigation will be provided, what enhancement measures will be provided, what ongoing monitoring shall be provided, and what governance arrangements will apply. Because of the continuous reporting back, there should be no surprises in a report. Good practice in SIA requires that these reports (and in fact the whole SIA process) be subject to professional peer review. Similar to the EIA process, there should also be a period of public comment on a report before it is accepted by regulatory authorities. Even where there is not a regulatory requirement, good practice would insist on a peer review process and acceptance of the final reports by the affected communities and the peer reviewers. Determining how to assess the acceptability of a report is complex. The following checklist provides a list of questions that should be considered by reviewers and/or community groups in their reading of an SIA report or SIMP.

## Description of the project and alternatives

- Does the report provide a sufficient description of the project including adequate information about the site, project design, size of the development, required workforce, likely timeframe, etc?
- Does the report describe the purposes and objectives the proposed development is expected to address, especially as they pertain to the sustainable development of the local area?
- Did the report consider reasonable alternatives to the project, including a 'no-development alternative', and give an indication of the primary reasons for the preferred alternative, taking into account the social consequences and sustainable development objectives?
- Is there discussion of project options yet to be decided and for which input is needed?
- Does the report describe the likely future landuses on the site and surrounding areas?
- Does the report describe all additional service demands (water, electricity, sewage, etc) and ancillary activities (dredging, quarrying, etc) that may be required as a consequence of the project or necessary to support the project (or make it clear that there are no extra demands)?
- Does the report document and discuss the contextual setting of the project and provide information on similar projects that have happened, are currently happening, or likely to happen in the vicinity of the current project to enable an adequate consideration of cumulative effects in the region?

## Description of methodology for the SIA

- Does the report adequately describe the overarching methodology for the SIA?
- Were the methods used for each of the component parts of the SIA satisfactorily described, appropriate, and properly undertaken?
- Was the stakeholder engagement strategy for the SIA adequately described?
- Were the methods used to predict the impacts adequately described and appropriate?
- Was the process to establish significance of the impacts described and was it reasonable?
- Was there a discussion of the limitations of the methodology and of the SIA in general?
- Was there evident adequate awareness of social research methods and appropriate reference to the literature on the methods of SIA and social research generally?
- Was there a discussion of the ethical implications (including informed consent) of the SIA and project?
- Was respect for Indigenous peoples clearly evident in the approach to social research methods and community engagement?
- Was there an attempt to utilise local knowledge in the design of 4
- Were traditional knowledge and Indigenous cosmologies and understandings included alongside western science and on equal terms in the impact assessments and other scientific reports?



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## Community profile and baseline data

- Is there a discussion of the extent of the area likely to be affected in social terms (the social zone of influence, or impacted zone)?
- Is there an adequate stakeholder analysis and reasonable identification and description of the different social groups within the region?
- Are vulnerable groups specifically identified and discussed?
- Are gender aspects and issues specifically considered?
- Are any Indigenous, tribal or other ethnic groups of special interest identified (or is it clearly stated that there are none in the region), and is this determination reasonable?
- Does the analysis identify and describe the various characteristics of the multiple affected stakeholder groups, especially aspects of their culture, economy, or livelihoods that may make them particularly susceptible to change?
- Does the analysis identify the local, national, and international organizations that are likely to have an interest in the project and especially those who have a link to affected stakeholders?
- Was local history discussed in sufficient detail to provide a reasonable understanding as to what current social concerns might be and what the potential for local conflict is?
- Was there identification of social indicators to be used for baseline data collection?
- Was there a justification provided for each social indicator?
- Is there a discussion about and use of existing (secondary) sources of baseline data?
- Was baseline data for the identified social indicators collected?
- Were appropriate targets and benchmarks established for each social indicator?
- Is there a discussion of data gaps and of the limitations of any data that exist or that may be collected?

## Community participation and engagement

- Was there a genuine attempt to identify and engage with a wide range of stakeholders and to inform them about the project and its implications, and invite their input?
- Is there evidence of how stakeholder input was actually utilised in the SIA and in project planning and development?
- Were lists of the groups who were approached as part of the SIA provided?
- Is it evident that diverse engagement methods were used to ensure inclusivity, and especially to ensure the participation of women, vulnerable groups, and Indigenous peoples if present?
- Were participatory processes established early in the SIA and the project so that the input from these processes could be used to influence the SIA and the design of the project?
- Were adequate resources available to support the participation of all stakeholders?
- Was engagement continuous, with adequate reporting back and validating of information?
- Was FPIC obtained for the project and for the SIA? If FPIC was obtained:
    - Was the basis by which FPIC asserted clearly established?
    - Was the basis by which ‘consent’ was determined discussed?
    - Was it truly prior?
    - Can the condition of ‘fully informed’ be reasonably established?



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## Scoping, assessment of impacts and significance determination

- Does the report indicate how scoping was done?
- Was there adequate stakeholder contribution to the scoping and assessment process?
- Does the report clearly identify all the various project activities and consider the impacts of these various activities on different stakeholders?
- Is there a description of impacts in terms of the nature and magnitude of the change and the nature, location, number, sensitivity and vulnerability of the affected stakeholders?
- Does the analysis consider how different groups are likely to respond to the impacts?
- Does the analysis consider the indirect (or second and higher order impacts) as well as the direct effects for all project phases (construction, operation and post-closure) on all groups?
- Were all reasonably likely impacts considered?
- Was there a comparison with other studies of similar projects elsewhere?
- Were the social and health implications of environmental impacts (changes of land use, emissions, changes in biodiversity or ecosystems, etc) considered and discussed?
- Were impacts discussed with reference to human rights?
- Is there an adequate discussion of how impacts were prioritised (significance determination)?
- Is there a discussion about the likelihood of and contingency plans for the management of abnormal events and operational accidents?
- Are the social consequences arising from abnormal events and accidents considered?

## Mitigation and enhancement strategies

- Does the report provide a description of the mitigation measures envisaged to avoid, reduce and/or remedy the significant adverse effects created by the project?
- Does the report discuss the reasons for choosing the mitigation methods, and describe options available, especially where mitigation is not self-evident?
- Does the report consider the likely effectiveness of the mitigation? Where the effectiveness is uncertain or limited, are the implications of this adequately discussed?
- Does the report discuss the extent and significance of residual impacts?
- Does the report discuss coping strategies for dealing with residual and/or cumulative impacts?
- Has there been adequate consideration of enhancement measures (i.e. changes to the project designed to enhance benefits to affected communities)?
- Is the potential for local content (jobs for local people, local procurement) well considered?
- Are the proposed mitigation and enhancement measures practical and feasible?
- Is there a discussion of likely changes in the impacts experienced over time, and the need for corresponding changes to mitigation and/or enhancement measures in the future?
- Was a community visioning process undertaken and/or is there a discussion of preferred or intended community futures?
- Is there a social investment contribution planned, and have the proposed social investment initiatives been adequately negotiated with the community?
- Are any proposed social investment initiatives sustainable and/or have the full support of appropriate local partners and/or government?
- Where the proponent takes on the responsibility for providing services and infrastructure, is there an exit strategy to pass on the responsibility to government, and in a context with weak government capacity, does the exit strategy include provisions for government capacity-building?



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## Grievance mechanisms and monitoring procedures

- Does the report discuss the establishment of a grievance mechanism?
- Is there evidence that the grievance mechanism is taken seriously, that affected stakeholders are aware of its existence, and would be inclined to make use of it if they had a concern?
- Has a monitoring process been established for all significant impacts?
- Are the impacted communities involved in the monitoring process in any way?
- Has there been any discussion about 'adaptive management', especially in relation to the monitoring and management of social impacts?

## Reporting, governance arrangements and overarching issues

- Is the report publicly available in appropriate languages – or at least have reasonable attempts been made to make information about the report accessible to local people?
- Is there a sense that the SIA and project development processes meet reasonable transparency expectations?
- Is information in the report logically arranged?
- Does the report describe how the community engagement undertaken has influenced the SIA, in terms of results, conclusions and/or approach taken?
- Were there adequate resources and time available to thoroughly investigate the social issues?
- Did the consultants seem professional, experienced, knowledgeable in social issues and SIA?
- Was there a peer review undertaken by a competent SIA professional?
- Did consideration of the social issues start early enough to enable effective management of social issues at early stages of the project?
- Is there evidence that project staff and senior company management have signed-off on the findings of the SIA and demonstrated their commitment to implement the recommendations and agreed strategies?
- Are all roles and responsibilities for future actions clearly identified and allocated to specific individuals or job designations? Do the Key Performance Indicators for their roles include these responsibilities?
- Have all other parties or agencies that are implicated in the report committed to the roles assigned to them in the report (e.g. local government, government agencies, third parties)?
- Have the roles of contractors and suppliers been adequately considered and is there evidence of a monitoring process to ensure that they comply with the intentions that arise from the SIA?
- Does the report give the impression that there has been adequate awareness of the project in a social sense?
- Was there cross-reference to any Environmental Impact Assessment, Health Impact Assessment and/or any other relevant documents/report that may have been commissioned by the proponent or other actor?
- Was there adequate connection to the SIA literature? (and specifically the International Principles for Social Impact Assessment and this Guidance document)?
- Does the report identify all appropriate local, regional, national and international policy and regulations responsible for protecting stakeholders?

# Conclusion

Social Impact Assessment should be considered as being the process of managing the social issues of projects. To be effective, the management of social issues needs to start from the moment a project is first conceived right through to well after closure of the project. Although the original understanding of SIA was as a regulatory tool, contemporary usage sees it as having multiple uses. SIA can still be applied in the context of national environmental regulation or because of the requirements of international donor agencies, but it can also be undertaken by a community to assist them in deciding whether to approve a project in an FPIC process, or in learning how to cope with change. SIA can also be undertaken by corporations as part of their responsibility to address their social and human rights impacts and their desire to earn a social licence to operate. In the time since its origins in the 1970s, the focus of SIA has changed from being primarily concerned about the negative impacts of projects, to being much more concerned about how projects might be enhanced to improve the benefits to communities, and to deliver shared value so that both communities and companies can benefit from projects.

The corporate responsibility to address its social impacts has also developed over time. Although companies still have an obligation to meet the requirements of national regulations, they also need to meet the expectations of many other stakeholders, including project partners, financial backers, international industry organizations, trade-union organisations, watchdog NGOs, local civil society, and local communities. With the rise of the digital age, NGOs, civil society stakeholders and local communities are becoming more aware of their rights, more empowered, and have more potential influence, more resources, and more reach. Furthermore, with the rise of the business and human rights agenda, there is also an international legal requirement and a legitimate public expectation that companies comply with human rights standards. These various expectations may not always be clear, coherent or coordinated, and may, in fact, be contradictory. SIA can assist in addressing the concerns of all stakeholder groups, but especially in mitigating harm and enhancing benefits.

SIA will have increasing relevance into the future and the demand for SIA will continue to grow for several reasons, including the increasing investment in developing countries. The combination of weak institutions and increasing land scarcity creates potential for increasing conflict between companies and local communities, especially where the risks are not identified early and mitigation plans not implemented early enough or not undertaken in cooperation with the impacted peoples themselves.

The intention of this document is to assist in determining what should be done to address project-related social impacts. It provides the definitive standard on good practice in social impact assessment and as such should be the guidance used not only by SIA practitioners, but also company social performance staff, government regulatory staff, the international financing community, NGOs and affected community representatives to debate and set expectations and benchmark performance in relation to the management of social issues arising from projects. Important to note, however, is that individual SIA practitioners work in a variety of settings, and are commissioned to do a range of tasks, but usually only a subset of the wide set of tasks described in this document. Therefore, what is reasonable to expect in any one situation will greatly depend on the specific contractual arrangements. Irrespective of the individual contractual arrangement, an SIA always has a duty of care to the client and to the impacted community to ensure that all key social issues are addressed.

A key point underpinning everything in this document is that rather than seeing SIA as being a cost to business, SIA should be seen as an appropriate, useful management process that reduces risk and brings benefits to companies and to communities – in other words, that operationalises the concept of shared value. There is thus a rock-solid, strong business case for projects to do effective social impact assessment and management.

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## Other key sources and links relevant to Social Impact Assessment & Management

International Association for Impact Assessment (IAIA), the professional association for all impact assessment practitioners, **http://www.iaia.org**

SIAhub, a resource-base and network for people specifically interested in SIA **http://www.socialimpactassessment.com**

The Practitioners Platform, a discussion forum for social performance practitioners in the extractives sector **http://managesocialperformance.com**

International Association for Public Participation (IAP2), a professional association promoting participation **http://www.iap2.org/**

The International Network on Displacement and Resettlement **http://indr.org/**

Anglo American SEAT **http://www.angloamerican.com/development/social/seat**

Equator Principles **http://www.equator-principles.com/**

IBA Community Toolkit: Negotiation and Implementation of Impact and Benefit Agreements. **http://www.ibacommunitytoolkit.ca**

International Finance Corporation Performance Standards and Guidance Notes **http://www.ifc.org/performancestandards**

International Council on Mining and Metals (ICMM), an industry association to address sustainable development issues **http://www.icmm.com/**

International Hydropower Association, **http://www.hydrosustainability.org**

IPIECA, the global oil and gas industry association for environmental and social issues **http://www.ipieca.org/**

Mining and Resettlement eLibrary, Centre for Social Responsibility in Mining, University of Queensland. **https://www.csrm.uq.edu.au/mining-resettlement/elibrary**

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## Glossary of SIA terms and concepts

***DISCLAIMER:*** *Below is a subset of the vocabulary of the field of SIA practice. While an attempt has been made to focus on SIA-specific terms, SIA practitioners operate in multiple discourses and the language used in SIA comprises not only SIA-specific terms but also terms from environmental impact assessment (EIA) and other impact assessment fields as well as from the industries in which SIA practitioners operate. The descriptions given here are intended to be an aid to understanding rather than being definitional statements. While many descriptions are original to this document (perhaps drawing on multiple sources), others are fairly standard statements that could be common to a range of sources.*

| | |
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| Actual impact | refers to the social impacts actually being experienced by communities, rather than to the impacts predicted to be experienced. |
| Affected publics | persons who live nearby; will hear, see, feel, or smell the proposed project; are forced to relocate either voluntarily or involuntarily; have an interest in the project or policy changes (whether or not they live in primary or secondary zones of influence); are interested in the potentially impacted resources; might normally use the land affected; or be affected by the influx of seasonal, temporary, or permanent residents associated with the project. |
| Alienation | a social science concept that refers to the social processes that alienate individuals (turn them into aliens or outsiders). The outcome of alienation is a lack of belongingness, and the experience of disconnectedness, meaninglessness and powerlessness, and a lack of agency. Thus it is a process that severely affects the mental wellbeing (and eventually physical health) of the individuals affected. It manifests itself in social isolation, despair, medical depression, and a range of other health-related behaviours. |
| Alternative livelihoods | (also called alternative economic opportunities) refers to the process of identifying, selecting and developing a range of income generating activities to replace or augment current livelihood activities of project-affected people. This is particularly important in the case of economic or physical displacement, but can also be a part of the benefits creation or social investment programs of the project. |
| Area of influence | in EIA, this refers to the physical area (and components such as air, water, soil) over which a project creates impacts (including abiotic, biotic and socioeconomic) caused by a project (and its associated activities). Thus it includes not only the land surface area but also the functioning of any marine and terrestrial ecosystems; airsheds and watersheds (surface or underground); and all social groupings including individuals, communities, companies (especially SMEs), organizations and governmental agencies. (also see Social area of influence) |
| Artisanal | 'artisanal' means working with the hands, and an 'artisan' is a skilled craftsperson. It is often applied to small scale miners, or subsistence fisherfolk. |
| Asocietal mentality | an attitude that humans don't count, or that social issues are not important and do not need to be considered. |
| Baseline | refers to the data for a set of selected indicators measured near the beginning of a project which are used to track change over time. The baseline data become a reference point, along with other benchmark values, against which future situations can be compared. Although the original baseline data refers to a specific point in time, the community profile should highlight trends in the project area so that a comparison can be made between what would likely have happened with and without the project. |
| Belongingness | the sense of belonging to a social group, which is an important human emotional need. A consequence of many projects is a reduction in the sense of belongingness, either because of the physical and social changes that takes place, the presence of newcomers, but also because of the alienation-inducing processes that take place. |

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| Benchmark | a comparison norm or point of reference. For each social indicator selected for monitoring, a benchmark should also be identified to provide some standard or value that can be used as a reference point. For example, the benchmark might be the WHO acceptable levels for air pollution or noise exposure, or for the expected number of doctors per thousand population. |
| Beneficiaries | the individuals, communities and organizations expected to benefit from the project or program. |
| Best practice | the set of guidelines, ethics, ideas, procedures and methods that represent the best (most appropriate) way of acting in a particular area of practice. Although best practice might be prescribed by a professional association, in general it is a vague concept referring to an aspirational benchmark. |
| Boomtown | a community, town or city that experiences excessively-rapid growth. |
| Brownfield | refers to project development that takes place in a location that has had previous experience with projects and where there are legacy issues to be addressed. |
| Camp followers | this term generally refers to the civilians who follow armies, typically servicing the needs of encamped soldiers by providing goods and services not provided by the military authorities, e.g. certain foods, laundry, alcohol and drugs, nursing, and sexual services. The term is now used more widely to describe those entrepreneurs who ply services to workers in construction camps and project sites. (also see Honeypot effect) |
| Capacity building | a coordinated process of interventions such as training programs usually focussing on building human capital and improving institutional practices and governance arrangements. |
| the Capitals | refers to a framework for thinking about sustainability and the achievement of development outcomes in terms of assets (or capitals) such as natural capital, human capital, social capital, financial capital, manufactured capital, and sometimes political and institutional capital, and cultural and spiritual capital. There are several frameworks that use the capitals as a core element, including the Sustainable Livelihoods Approach. |
| Causal pathways | a concept that connects with evaluation and systems thinking. It refers to the causal relationships (at least to the correlations) between various elements in a system. In SIA, it refers the sequences of the experiences of primary and secondary impacts and between the social change processes and social impacts. |
| Citizens' jury | a deliberative technique where decision making (perhaps about selecting the best alternative) is given to a panel of lay people (around 12) selected from the public who are entrusted to deliberate on the relevant issues on behalf of the community. Although intended to be a lay rather than expert panel, it is nonetheless expected that they will learn about the relevant issues and ask questions from experts and call for information as needed. Decisions made by citizen's juries are like to have greater legitimacy among the local community than those made by expert-driven processes. |
| Civil society | the network of individuals and groups (both formal and informal) – and their connections, social norms and practices – that comprise the activities of a society and that are separate from its state and market institutions. It includes religious organizations, community groups, foundations, guilds, professional associations, labour unions, academic institutions, media, advocacy or pressure groups, political parties, etc. |
| Closure planning | the process of planning and managing a project site for the post-closure situation, in other words, after the mine or factory is closed. Good practice SIA ensures that post-closure planning is built into the planning process and considered at an early stage of construction. This is very important especially in a mining context where there is volatility of resource prices that affect the viability of the mine. |

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| Commitments register | a formal public document that records any statement of promise made by the company to the community especially in relation to any promised mitigation or benefit. |
| Commodification | the processes by which local culture and local cultural artefacts are turned into commodities and thereby religious traditions, local customs and festivals are reduced to conform to expectations of those buying. It is a concept from the social impacts of tourism, but can happen in any situation where a local culture comes into contact with a wealthy group of outsiders. |
| Common law | Common law refers to laws and the interpretation of laws perceived to exist in a community and manifested by judges in court statements (precedents). Common law can be contrasted with statutory law, and has legal standing in countries that derive their legal systems from the English system. European continental systems (e.g. Roman law and French or Napoleonic law) do not recognise common law. In some ways, common law is like customary law. |
| Communitas | a social science term (from Latin) which means a strong sense of community, especially as built through participation in ritual or community celebration. |
| Community | a commonly-used, yet contested concept that can apply at different levels, although generally refering to a place-based grouping of people who are presumed to have some sense of shared identity, some shared interactions of everyday life, and some common social and political institutions. Although individuals experience some social impacts at a personal level, the general assumption in SIA is that people live, work and play in social groupings called communities, which are therefore a primary focus in SIA. |
| Community agreements | (see Impacts & Benefits Agreement) |
| Community assets | the resources in the community that can be used to improve development outcomes for the community. They include the people and organisations who can help achieve community goals, but it also refers to the places, attractions, and physical resources whether natural or artificial that are valued by the community. |
| Community cohesion | refers to the sense of harmony in a location (rural area, town or city), which can be established by the levels of: acceptance and valuing of social diversity; a shared sense of belonging across all groups; a broadly accepted vision and image of the location; reasonably similar life opportunities and access to services; and positive social relationships between people from different backgrounds. |
| Community development | The long-term process whereby people who are marginalized or living in poverty work together to identify their needs, create change, exert more influence in the decisions which affect their lives and work to improve the quality of their lives, the communities in which they live, and the society of which they are part. |
| Community Development Agreement | a concept very similar to an Impacts & Benefits Agreement (IBA), but an agreement that might be initiated by government rather than the bilateral agreement between company and community that an IBA tends to be. |
| Community engagement | Community engagement is a term used to describe the many ways by which people can interact with and be involved in decision-making processes. Community engagement is similar to 'public participation' and 'public involvement', with these terms often used interchangeably. However, community engagement is the current preferred term as it emphasise a greater depth of involvement or engagement in the decision-making process and more respect for people. It also connects to a different discourse, and represents the development of understanding in the continuum from consultation to empowerment. |
| Community grievance mechanism | a grievance mechanism specifically designed to enable access by members of project-affected communities. |

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| Community infrastructure | Public and private services and facilities that contribute to the general quality of life (e.g., health, transportation, power, education, water and water quality, sanitation services). |
| Community mindedness | the extent to which individuals in a particular location have a notion of being part of a community, and of helping out in the community by participating in community activities, and being a good neighbour (i.e. having neighbourliness). |
| Community profile | a description of the communities likely to be affected by a planned intervention. |
| Community visioning | a process of developing consensus about what future the community wants, and then deciding what is necessary to achieve it. It is both the process of creating a vision, and the product of the vision. |
| Company town | a settlement where the vast majority of people work for the same company or at least one of the many companies servicing the same project. |
| Compensation | where impacts cannot be avoided compensation means making restitution to people either individually or collectively. Compensation can be in the form of cash payments, or it can by in the form of the provision of other development activities, such as the provision of a hospital or a school or a public library. While compensation can be in response to a legal requirement stemming from the property rights of the affected community, it can also be done by the proponent as a goodwill gesture or as a negotiated outcome. |
| Competent authority | any person or organization that has the legally-delegated or invested authority, capacity, or power to perform a designated function. In SIA/EIA terms, it usually refers to the authority that grants an environmental licence. (also see Regulatory agency) |
| Compliance | means complying with the law and any regulations governing the activity. In an impact assessment context, it refers to the extent to which project licencing conditionalities have been observed. Generally it is expected that there would be a periodic audit or follow-up to ensure compliance. |
| Compliance Advisor Ombudsman (CAO) | an independent office (reporting directly to the President of the IFC/World Bank Group) that responds to complaints from those affected by IFC-financed projects. It only considers whether the IFC has followed appropriate procedures. |
| Complicity | a word used in the human rights discourse. Companies must not be complicit in the human rights abuses of third parties. Complicity is regarded as comprising any of the following: caused or contributed to the human rights abuse by enabling, exacerbating or facilitating the abuse; knew or should have foreseen that human rights abuses would be likely to occur from its conduct; and was proximate to the human rights abuse either geographically or through the strength, duration or tone of its relationships. |
| Conditionalities | in development assistance, this refers to the use of conditions attached to a loan, debt relief or bilateral aid; in environmental licensing it refers to the conditions of the licence. |
| Conflict resolution/ management | development interventions often change power relationships between groups in society. Some groups stand to lose while others gain from such interventions and as a result conflicts may emerge. Conflicts are a normal part of social interaction, but when they become dysfunctional they have a negative impact on all who are involved. Effective mechanisms and techniques for conflict prevention, management and resolution are thus necessary for resolving conflicts or keeping them within acceptable limits. Transparency and information-sharing can eliminate conflicts caused by incomplete or distorted knowledge. Acceptance and ample space for expressions of different viewpoints can prevent the development of more destructive forms of conflict. |



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| Consent | another word for being in agreement with something. It can also mean having the power to be able to give or withhold approval for a project. Thus a regulatory agency has responsibility for determining consent conditions. In some circumstances, local people might also have the ability to give or withhold consent for a project (see FPIC). The concept of consent is highly associated with trust. An SIA practitioner can often build consent for the SIA process (if not the project) by showing that there is an issue that needs to be addressed, that a broad spectrum of groups are involved in addressing it, and that the process to solve the problem is fair. |
| Cosmology | the understanding of the origin, history, evolution and cultural laws pertaining to the cosmos or universe in a particular culture or mythological system. |
| Cost Benefit Analysis | (also called Benefit-Cost Analysis) is an economics approach to assess alternatives for a business usually by determining the ratio of benefits to costs. In past decades, it was widely used in impact assessment, but it has not been popular in SIA because it seeks to render all impacts in monetarised terms only. |
| Counterfactual | In psychology, a counterfactual refers to a mental representation or image of an alternative trajectory, past or future, as a way of conceiving other possibilities to what actually happened. This enables individuals to process their feelings about past events (such as in relation to blame, guilt, regret, and 'why me?' concerns, etc) and also as a way of learning from experiences. This learning can be formalised in scenario analysis. In evaluation circles, however, counterfactual has a different meaning, referring to a comparison between what actually happened and what would have happened in the absence of the intervention. |
| Cultural affrontage | a deliberate act that is insulting or deeply offensive, such as the violation or desecration of sacred sites, or the deliberate breaking of taboos or other significant cultural mores. |
| Cultural heritage | refers to the legacy of physical artefacts and the intangible qualities of a group or society that are inherited from past generations, maintained in the present, and bestowed for the benefit of future generations. Cultural heritage includes tangible culture (such as buildings, monuments, books, works of art, and artefacts), intangible culture (such as folklore, traditions, language and traditional knowledge), and natural heritage (including culturally-significant landscapes, important wildlife habitats, and biodiversity). |
| Cultural heritage impact assessment | the process of evaluating the likely impacts of a proposed development on the physical manifestations of a community's cultural heritage including sites, structures, and remains of archaeological, architectural, historical, religious, spiritual, cultural, ecological or aesthetic value or significance. Impacts on intangible cultural heritage would be assessed in a cultural impact assessment. |
| Cultural impact assessment | a form of impact assessment that considers the impacts of a project specifically on the culture of a particular social group (such as an Indigenous or specific ethnic group). It would consider, amongst other things, the values, belief systems, customary laws, language(s), customs, economy, relationships with the local environment and particular species, social organization and traditions of the affected community. Given that cultural impacts should be part of SIA, cultural impact assessment is a subcomponent of SIA, but is closely tied to other social impacts making it a meaningless distinction, except insofar as it signifies the perspective and purpose of the impact assessment – i.e. SIA directed to understanding the social impacts of a project on the culture of the local community. |
| Cultural sensitivity | an individual quality of being aware of cultural differences and of knowing how to operate in cross-cultural situations. Many social impacts arise because of the lack of cultural sensitivity of many project staff. |

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| Culture | the material and non-material aspects of a way of life that are shaped and transmitted among members of a community or a larger society. Sometimes referred to as the shared beliefs, values, norms, behaviours, language, and material objects that are passed from one generation to the next. |
| Cumulative impacts | the successive, incremental and combined impacts of one or more projects (existing, current and foreseeable future projects) on society, the economy or the environment. They can result from the aggregation and/or interaction of impacts within a social or environmental system and are defined from the perspective of the people or environment experiencing them. |
| Customary law | cultural practices and beliefs which are such a vital and intrinsic part of the social and economic system of a particular culture that they are treated as if they were laws and given (semi)legal standing – thus customs that are accepted as legal requirements or obligatory rules of conduct. |
| Customary rights | rights which apply because of custom or culture. |
| Cut-off date | a term used in resettlement processes to refer to the date after which people will not be not included in the list of identified project-affected persons and therefore entitled to resettlement assistance and compensation. |
| Deliberation | (and deliberativeness) a multidimensional concept that can be defined as dialogue intended to induce deep reflection (i.e. serious consideration) of options and possibilities in an open and inclusive way (i.e. without the intrusion of power or politics), and that considers the concerns of all stakeholders. |
| Deliberative space | a physical setting that is conducive to deliberativeness. |
| Demonstration effect | the consequences on individuals that come from observing other people. In SIA this can include situations where members of a host community try to emulate the lifestyles, behaviours, attitudes and/or language of newcomers such as expat workers or tourists. This can lead to many negative social impacts, including increased costs of living, frustration, and problematic culture change. Potentially it can also lead to positive social impacts in the form of knowledge transfer between international contractors and SMEs. |
| Direct impact (or effect) | an impact which occurs as a direct result of the planned intervention. May also be called primary impact or first order impact. In SIA, it refers to social changes and social impacts caused directly by the project itself, such as the annoyance to people of noise generated by machinery associated with the project. |
| Disclosure | often stated as 'full and frank disclosure', a policy of 'open disclosure', or as a 'duty of disclosure', this is a term with legal and semi-legal connotations that refers to the obligation of parties in a negotiation to reveal everything that is considered relevant to the matter under consideration (i.e. materiality). |
| Discourse | 'discourse' implies everything around language and conversation, including everything that language use entails, such as the active construction of thoughts, identities, and actions. It is a social construction that provides the set of possible statements about a given area, and organises and gives structure to the manner in which a particular topic, object, or process is to be talked about. Discourse provides descriptions, rules, permissions and prohibitions of social and individual action. |
| Displacement | whereas resettlement is the active process of relocating people because of a project, displacement is the personal and social experience of the upheaval of relocation, the process of losing one's sense of place. In resettlement processes, physical displacement refers to the loss of housing resulting from project-related acquisition of land and/or restrictions on landuse that require the affected persons to move to another location. Economic displacement refers to situations where people's houses are not affected but where there is a loss of other assets or access to assets (e.g. agricultural land) that will result in a disruption of livelihoods and associated loss of income. |



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| Dispute resolution process | a concept relating to agreements and contracts (and often a clause within them) about what will happen if they is a disagreement about the interpretation of the contract/agreement or a disagreement between the parties to the agreement. It is different to a grievance mechanism. |
| Due diligence | in general terms, due diligence is an investigation a person or company would conduct before signing a contract or before making an acquisition, especially in situations where there may be some risks. In SIA, due diligence refers to much the same concept except with more reference to the UNGP Principle 17 which states that "In order to identify, prevent, mitigate and account for how they address their adverse human rights impacts, business enterprises should carry out human rights due diligence. The process should include assessing actual and potential human rights impacts, integrating and acting upon the findings, tracking responses, and communicating how impacts are addressed." |
| Duty-bearer | in the human rights-based approach, human rights entail both rights (and thus rights-holders) and obligations (and thus duty-bearer). In human rights law, duty-bearers tend to be primarily States, but arguably also include all individuals, but particularly companies, and their suppliers and contractors. Under international law, States assume obligations and duties to respect, to protect and to fulfil human rights. The obligation to respect means that States must refrain from interfering with or curtailing the enjoyment of human rights. The obligation to protect requires States to protect individuals and groups against human rights abuses. The obligation to fulfil means that States must take positive action to facilitate the enjoyment of basic human rights. At the individual level, while we are entitled our human rights, we should also respect the human rights of others. |
| Duty of care | An obligation to take reasonable care to avoid causing foreseeable harm to another person or their property. An SIA practitioner has a professional duty of care to the client and an ethical responsibility to the community to ensure that all appropriate issues have been raised. |
| Economic dependency | a situation where a local community or region depends heavily on one company or industry, in other words, when a high proportion of people in the region work for that company or industry. |
| Economic displacement | refers to the upheaval and social impacts (i.e. displacement) that are due not to relocation of the place of residence, but to the loss of economic livelihood, such as when farmers lose their farming land, or when water pollution destroys the livelihoods of fishers. |
| Ecosystem services | the idea that the environment (an ecosystem) provides a range of services (and products) on which humans depend. These are usually regarded as being: provisioning (e.g. the production of food and water); regulating (e.g. the control of climate and disease); supporting (e.g. nutrient cycles and crop pollination); and cultural (e.g. spiritual and recreational benefits). To help inform decision-makers, ecosystem services are often assigned economic value. |
| Elite capture | a situation in which resources that were intended for the benefit of the larger population are usurped (captured) by a small wealthy, powerful group within society, an economic, political, educational, or ethnic elite. |
| Emerging market | another way of referring to a developing country. |
| Eminent domain | refers to the power of the State to compulsorily acquire private property. This might be done to resume (expropriate) land for highways, airports, etc. Occasionally the State extends its power to enable private sector projects to proceed when they are deemed to be in the national interest. |



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| Empowerment | is the enhancement of the assets and capabilities of diverse individuals and groups to engage and influence economic and social institutions, and to increase the accountability of public institutions. A participatory process which places or transfers decision-making responsibility and the resources to act into the hands of those who will benefit. This can include (i) capacity building for stakeholder organizations; (ii) strengthening legal status of stakeholder organizations; (iii) stakeholder authority to manage funds, hire and fire workers, supervise work, and procure materials; (iv) stakeholder authority to certify satisfactory completion of project and establish monitoring and evaluation indicators and (v) support for new and spontaneous initiatives by stakeholders. |
| Enhancement | deliberate attempts taken in the design and subsequent phases of projects to ensure the achievement of a wide range of direct and indirect development outcomes. |
| Environment | a very vague concept that is defined in different ways in different settings. In some jurisdictions, it includes ecosystems and their constituent parts, including people and communities; natural and physical resources; the qualities and characteristics of locations, places and areas; and the social, economic, cultural, aesthetic and heritage aspects of all these elements. In other jurisdictions, the environment refers only to the biophysical elements, such as water, air, soil, flora and fauna. |
| Environmental bond | a financial instrument (often in the form of an escrow account) that provides surety to ensuring that a project will meet its environmental rehabilitation requirements. |
| Environmental Impact Assessment (EIA) | a formal process used to predict the likely environmental consequences (positive or negative) of a plan, policy, program, or project prior to implementation, usually as part of the regulatory (environmental licensing) procedure. |
| Environmental Impact Statement (EIS) | the formal document produced by an EIA which is submitted to the competent authority. |
| Environmental licence | an administrative permit issued by a competent authority by which the operator of a productive activity or an infrastructure work is given permission to carry out the actions for which the license is requested, although perhaps on the basis that a number of operating conditions are fulfilled, certain use limitations are respected, and certain measures are implemented for containment, minimization and avoidance of any social or environmental impacts the activity or work may cause. |
| Environmental Management System (EMS) | an on-going and planned series of activities, based on the concept of continuous improvement, undertaken by a business to better manage its environmental impacts. It is prescribed by the ISO 14001 Standard. |
| Escrow account | refers to monies held in trust by a third party according to terms of an agreement and which are only released when the conditions of the agreement have been filled and/or with the consent of the contracting parties and/or by a court order or other legal action. |
| ESHIA | Environmental, Social and Health Impact Assessment. |
| Equality impact assessment | usually abbreviated EqIA to differentiate it from EIA, assesses the equity and discrimination considerations in all policies and strategies especially with respect to vulnerable groups. |

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| Equator Principles | a corporate social responsibility and sustainability framework for the global finance industry. More specifically, it is a risk management framework adopted by financial institutions (i.e. banks) for determining, assessing and managing environmental and social risk in projects anywhere in the world and for all industry sectors. It is primarily intended to provide a minimum standard for due diligence to support responsible risk decision-making. Banks that adopt the Equator Principles commit to implementing the principles in their internal environmental and social policies, procedures, and standards for financing projects and agree to "not provide Project Finance or Project-Related Corporate Loans to projects where the client will not, or is unable to, comply with the EP". Essentially the EP are a set of high level principles. For operational guidelines, the EP requires compliance with the IFC Performance Standards. |
| Ex-ante assessment | in advance. Most impact assessments are ex-ante, a prediction about the likely impacts of a planned intervention; in other words, about something that has not yet happened. |
| Ex-post assessment | after the event. Ex-post assessments are in effect evaluations of the impacts of a particular project or policy. |
| Exit strategy | in an SIA/project sense, this refers to the consideration that a company needs to give as to how they will extract themselves from long-term obligations that are not core business. |
| Expropriate/expropriation | refers to the ability of a public sector agency, or a corporation authorised by government, to acquire land and other resources, without the consent of existing users or residents. (also see Eminent domain) |
| Externality | an economics terms that refers to the costs (and thus impacts) that are considered to be external or irrelevant to the consideration being made, thus typically the environmental and social impacts. A principle of sustainability is to internalise the externalities. |
| Facilitation | the process of enabling groups and organizations to achieve their goals by assisting them in the processes they use to collaborate with each other. A facilitator is usually independent, trained and experienced in facilitation skills, and has a repertoire of techniques to use, selected according to the purpose and interests of the group being facilitated. In an SIA and/or community engagement process, it is a facilitator who normally manages the engagement processes. Key skills are impartiality, an ability to set people at ease, a good understanding of social process and a good knowledge of a wide variety of techniques and of when to use which technique. |
| Facipulation | a made-up word that combines the words facilitation and manipulation. It refers to the feeling that people have when they participated in an engagement process but were left feeling that they had been manipulated. |
| Fear of crime | refers to an abnormal fear people experience about being a victim of crime. Rapid change in a community can increase people's fear of crime so that their fear is out of proportion in relation to the actual probability of crime. Fear of crime is a very debilitating condition because it changes people's behaviour, affects how they feel about their community and it affects their general wellbeing. |
| Fenceline | an expression that refers to the boundary around a project site. It is intended to be a way of designating between internal issues and external issues. However, while this may be evident in a technical sense, it is not straightforward, and in terms of social and human rights issues is irrelevant. |
| Fenceline communities | refers to the communities that are the immediate neighbours of the project and that are particularly vulnerable to the direct impacts of a project, such as noise, dust and vibrations. |

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| FIFO | fly in, fly out. An acronym that refers to the use of workers who are not normally resident in the vicinity of the project and who are brought in, usually for blocks of time, as workers. |
| First order impact | the impacts that are the immediate, direct consequences of a project. |
| Fixed income earners | refers to those people whose income (from jobs or pensions) is fixed, i.e. not adjusted for inflation or cost of living issues. Boomtowns usually experience local inflation. While people who are associated with the project are paid a sufficient amount to cope with the cost of living increases (and are usually the cause of the inflation), many people receive incomes that are not adjusted to local levels. These include not only pensioners, but in effect people on salaries that are set at a national level like nurses, teachers, police officers, and other people who work in government. |
| Footprint | is a vague term that can be shorthand for ecological footprint or a carbon footprint, but can also mean the immediate physical space occupied by a project. |
| Foreign direct investment | a business term referring to investments that relate to the gaining of a controlling ownership (typically regarded as being 10% or more shareholding) in a business enterprise in one country by an entity based in another country. |
| FPIC | free, prior and informed consent (see the discussion about this in this document). |
| Front end loading | a term from project management that implies spending more money upfront in order to have a better design and thus save money later on. Not to be confused with a 'front end loader', which is a vehicle (piece of equipment) that can scoop up dirt and other materials. |
| Gatekeeper | a person or institution that controls access to something. Gatekeepers can have formal or informal roles. In an SIA context, the concept often refers to the individuals who can the power to help or hinder the access of the consultants to a particular community. In other words, they have a key influential position. |
| Gender | refers to the socially-constructed roles ascribed to males and females. These roles are learned, change over time, and vary widely within and across cultures. |
| Gender analysis | a process used to consider and understand the gendered nature of the implications of a planned intervention on women, as well as of men, in the cultural context of the communities affected. A gender analysis should consider sex and gender differences. |
| Gentrification | the gradual process by which a location (typically an inner-city suburb or a village in an aesthetic location) transforms from being working class to middle or upper-middle class in character and composition. A consequence of this process is increasing property values and home rental cost leading to the displacement of former residents. When gentrification leads to touristification, it can also lead to conflict between established residents (old-timers) and tourists and/or the new residents (newcomers). |
| Good governance | a normative understanding about how governance (of any organisation) should occur, including a commitment to accountability, transparency, the rule of law, capacity building, inclusive and participatory process. |
| Good practice | what is currently considered to be appropriate and expected (i.e. conventional rather than cutting edge) in a field of practice. In contrast, best practice means cutting edge or leading, and thus good to advocate, but cannot be expected in all circumstances. |

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| Governance | refers to the ways organizations, institutions, businesses, and governments manage their affairs. It is the act of governing, involving the application of laws and regulations, but also customs, ethical standards and norms. (also see Good governance) |
| Governance gap | there are many governance gaps, but in general they refer to the difference between the ideal (or least what would normally be expected as proper) and the actual practice of governance. In the impact assessment and business & society discourses, the gap tends to refer to the lack of scrutiny over multinational companies in their activities in developing countries. |
| Greenfield | refers to project development that takes place somewhere with no previous development experience, in other words no legacy issues. |
| Grievance | any perceived concern evoking an individual or group's sense of entitlement or having been wronged, based on law, contract, explicit or implicit promises, customary practice or general notions of fairness. |
| Grievance mechanism | a formal, legal or non-legal (judicial/non-judicial) process to address complaints that can be accessed by individuals, workers, communities and/or civil society organisations who are or feel they are being negatively affected by the activities of a project or business. |
| Guiding Principles | tends to refer to the United Nations *Guiding Principles on Business and Human Rights.* |
| Higher order impact | the indirect social impacts that happen after the immediate first order impacts in the chain of impacts that arise from a project. |
| Homelessness | a personal situation of being without a home, of not having a regular place to stay. At one level it can refer to people of no fixed abode who depend on emergency housing services who otherwise would sleep on the streets (i.e. 'sleeping rough'); at another level it can mean the feeling of alienation such that even though there may be a physically adequate place of residence, other emotional elements about it mean that it does not feel like home. |
| Honeypot effect | or project-induced in-migration; people may move to the project site in an attempt to become regarded as an affected person and therefore eligible for compensation or in search of work or economic opportunities that arise from the project. |
| Host communities | refers to those communities that are near to project sites, that host the project and its workers, in other words the impacted communities. In resettlement planning, it refers to the existing communities that will absorb people who are being relocated. |
| Human capital | the education, skills, knowledge, ability to labour, and good health that together enable people to pursue their livelihood objectives. (also see Capitals) |
| Human rights | universal legal guarantees protecting individuals and groups against actions and omissions that interfere with fundamental freedoms, entitlements and human dignity. Human rights law obliges Governments (principally) and other duty-bearers to do certain things and prevents them from doing others. |
| Human rights-based approach (human rights lens) | refers to a conceptual framework that is normatively based on international human rights standards and operationally directed towards promoting and protecting human rights. It is an approach (to health, to development cooperation, etc) that: (1) positions human rights as a core element; (2) demands accountability and transparency among duty-bearers; (3) fosters empowerment and capacity development of rights-holders to, inter alia, hold duty-bearers to account; (4) views meaningful participation of rights-holders as a right, not simply as best practice; and (5) ensures non-discrimination as well as prioritises vulnerable groups. |

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| Human rights due diligence | refers to the expectation under the United Nations *Guiding Principles on Business and Human Rights* that companies should fully satisfy themselves that a proposed business action, transaction or acquisition has no hidden human rights risks (in other words, not only risks to the company, but also risks to people and communities). Since many social impacts are also human rights issues, affected stakeholders may be rights-holders with legal rights. |
| IAIA | International Association for Impact Assessment, **http://www.iaia.org** |
| IAP2 | International Association for Public Participation, **http://www.iap2.org** |
| ICMM | International Council on Mining and Metals, **http://www.icmm.com** |
| IFC | International Finance Corporation, the private sector lending arm of the World Bank Group. It is particularly significant because its performance standards have become an international benchmark, and are the basis of the Equator Principles. |
| Impact | an economic, social, environmental, and other consequence that can be reasonably foreseen and measured in advance if a proposed action is implemented. |
| Impact assessment | the process of identifying the future consequences of a current or proposed action. |
| Impact equity | the notion that the impacts in a society or of a project should be shared in an equitable manner, at least that there should be consideration given to the fair distribution of negative and positive impacts. For example, the flight paths for an airport might be adjusted to share the noise burden rather the same people having all the noise. |
| Impact history | refers to the past experience a community has had with other projects. This affects the way they relate to new projects and how much trust they might have. It also means that there may be legacy issues that a new operator has to deal with. |
| Impact pathways or impact chains | refers to the links between primary impacts (first order impacts) and secondary impacts; as well as the links between social change process such as inmigration. |
| Impacted communities | those communities (the host communities) that are impacted by a project. |
| Impacts & Benefits Agreement (IBA) | a legally-binding agreement between a company and a community (sometimes also involving government) that outlines the likely negative impacts a project will create, the mitigation efforts a company will undertake, and the extent of contributions the company will provide to the community in the form of jobs and other benefits such as social investment contributions. |
| Impoverishment | the process of becoming impoverished (resulting in poverty). The loss of livelihoods from the displacement caused by projects can lead to impoverishment. |
| Indicator | (see Social indicator) |
| Indigenous knowledge | (see Local knowledge) |
| Indigenous people | broadly defined as a distinct social and cultural group exhibiting the following characteristics to some extent: self-identification as a member of a distinct cultural group and recognition of this identity by others; collective attachment to a geographically-distinct habitat or ancestral territory and to the natural resources therein; customary cultural, economic, social, and/or political institutions that are separate from those of the dominant society or culture; a language which often different from the official language of the country or region. |

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| Indirect impact (effect) | an impact which occurs as a result of another change which is caused by a planned intervention. In SIA, an indirect effect might be caused by a physical change to the environment. For example, a mine might increase river turbidity which might reduce the supply of fish which may reduce the economic livelihoods of fishing dependent villagers. These can also be secondary effects, second or higher order effects. |
| Influx management | the process of managing the large numbers of people who come to project sites in search of economic opportunities (see Honeypot effect). |
| Informal economy | refers to that part of the economy that avoids regulation, taxation or control by government, either because it operates illegally, or because it operates on a small-scale, cash basis. |
| Informal settlements | townships that develop informally, that is without proper planning and usually in violation of building codes and planning schemes, typically on land to which the inhabitants do not have proper entitlement, often using discarded materials to make temporary dwellings. |
| Informed consent | the most basic ethical principle in undertaking research with humans; basically that the intended research participant has the right to decide whether or not to participate, and that they should make this decision on the basis of full information about the research and the likely risks to them. Informed consent is often recorded by the participant signing an Informed Consent Form. SIA practitioners should practice informed consent with the participants in SIA data collection. |
| Intangible cultural heritage | (see Cultural heritage) |
| Interested and affected publics | groups, organisations, and/or individuals who believe that an action might affect them or who are otherwise involved in the decision process (also called stakeholders). (also see Affected parties) |
| Intrinsic value | a philosophical concept that an object or entity (such as nature, a specific location, a rare species) has an inherent value or quality beyond its instrumental or use value to humans. |
| Involuntary resettlement | the resettlement of people by a project in situations where the state power of eminent domain was exercised or threatened to be applied (also see Resettlement). |
| IPIECA | the global oil and gas industry association for environmental and social issues **http://www.ipieca.org/** |
| Irremediability | irreparable harm, negative impacts that can not be mitigated or redressed. |
| Irreparability | unable to be repaired. |
| Key Performance Indicators (KPIs) | refers to the indicators that are set to measure the performance of a company or person. Monitoring indicators are not usually regarded as KPIs, but the adequacy of monitoring should be a KPI for the manager responsible for monitoring; and the lack of exceedances should be a KPI for a company. |
| Knowing and showing | a phrase made popular by John Ruggie. Rather than companies be vulnerable and exposed by being named and shamed, instead they should demonstrate that they have internalized their respect for human rights by their commitment to due diligence processes. |
| Land tenure system | the legal arrangements by which the ownership of land and any process for the intergenerational transfer or sale of land ownership are formally established. |
| Landscape restoration | (see Rehabilitation) |



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| Latent conflict | refers to conflict in a community that is latent, that is hidden or concealed. Project staff may not realise the presence of tension in a community. |
| Leading practice | in effect the same as best practice, but perhaps with the idea that what is leading always changes and therefore it is a relative concept. It tends to refer to an attitude of a company (to be a leading practice organisation) rather than being a property of practice. |
| Legacy issues | The general meaning of legacy is something that is left behind, such as when a person dies (what they leave to others in their will), or when they retire from their job (when they have created value or made a mess), but it can also refer to what a project or a company leaves behind. Although the word is arguably neutral/bidirectional and can mean the positive state of affairs and contribution to development outcomes, in SIA it typically refers to the mess left behind by past projects. In the extractive sector, it largely refers to the pollution and contamination left behind, such as acid mine drainage. It is important to appreciate that the legacy issues of other projects affect the trust of a community to accept a new project. |
| Legitimacy | a concept that means that the actions of one party are considered by an individual or group to be desirable, proper, appropriate, or at least acceptable from the normative perspective of the other party. Legitimacy can be interpreted in multiple ways, including as legal legitimacy, political legitimacy, moral legitimacy and social legitimacy. On its own, in an SIA context at least, 'legitimacy' is normally understood as being 'social legitimacy'; the extent to which an action is socially acceptable. |
| LGBT/LGBTIQ | lesbian, gay, bisexual, transgender, intersex and queer people. Some other variants of the acronym also include 'questioning'. LGBT, LGBT+ and LGBTIQ are the typical inclusive acronyms used in discussions of sexual orientation and gender identity (SOGI). LGBTIQ people are frequently discriminated against and therefore are amongst the marginalised and vulnerable groups in society. |
| Licensing process | the process by which an operator obtains an environmental licence or permit, and the process by which the regulatory agency determines whether it should be given. |
| Lifeworld | a social science concept that refers to the lived experiences of people and to their everyday lives. It implies taking their perspective in the analysis or narrative presented. |
| Linear projects | projects like pipelines, highways, railways, transmission lines and irrigation systems that affect a narrow strip of land but extend for many kilometres. |
| Liveability | the aspects of a place which make its inhabitants happy to live and work there, and which provides a high quality of life for all its inhabitants. |
| Livelihood | refers to the way of life of a person or household and how they make a living, in particular, how they secure the basic necessities of life, e.g. their food, water, shelter and clothing, and live in the community. (also see Sustainable livelihoods) |
| Livelihood Restoration and Enhancement Plan | a plan produced as part of a resettlement process to restore and enhance people's livelihoods after being resettled or economically displaced. |
| Local content | refers to the requirement, expectation or commitment of a company to ensure that value is retained locally through employment and/or procurement. |
| Local knowledge | the knowledge that people in a given locality or community have developed over time and which they continue to develop. It refers to the collection of facts and systems of concepts, beliefs and perceptions that people have about the world around them. It also includes the way people observe and measure their surroundings, how they solve problems and validate information. A wide range of terms is used: Indigenous Knowledge, Indigenous Technical Knowledge, Traditional Knowledge, Traditional Ecological Knowledge or Traditional Environmental Knowledge, and Aboriginal Knowledge. |

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| Local procurement | refers to the deliberate company policies and enabling strategies to procure goods and services from local suppliers so as to enhance the benefits of the project to the local community. |
| Marginalised groups | (see Minority groups and Vulnerable groups) |
| Marginalisation | refers to the social and economic processes that make minority groups and/or vulnerable groups worse off. |
| Materiality | a legal concept that refers to whether something is relevant to the matter at hand. For example, it can refer to what should be disclosed as part of good faith negotiation. It can also refer to what should be considered in sustainability reporting. |
| Mental health | simply put is the level of psychological wellbeing and the absence of any mental disorder. Mental health includes an individual's ability to enjoy life, as well as their subjective wellbeing, perceived self-efficacy, autonomy, competence, and self-actualization of their intellectual and emotional potential. |
| Microfinance | a variety of banking services (typically the provision of small loans) to assist low income people (especially women) to establish small businesses. Microfinance arrangements are very important because they provide finance for people who otherwise are excluded from access to capital due to the small value of the requested loan, their low income, lack of collateral, and non-existent or poor loan history. |
| Mindmap | a mindmap is a diagram that is a way of presenting ideas and thoughts; mindmapping is a process of organising information and ideas. |
| Minority groups | a social science term used to refer to members of designated social groupings that are differentiated or differentiable from mainstream society. They typically: experience discrimination and subordination; have physical and/or cultural traits that set them apart, and for which they are marginalized by the dominant group; a shared sense of collective identity and common burdens; socially-shared rules about who belongs and who does not determine minority status; and tendency to marry within the group. |
| Mitigatability | able to be mitigated. |
| Mitigation | the process of devising and implementing processes, procedures and/or changes to a planned intervention in order to avoid, reduce or minimise, or to compensate (offset) for impacts likely to be experienced. |
| Mitigation hierarchy | a framework for planning mitigation actions. A short form of it is: Avoid, Reduce, Repair, Compensate. A longer form goes: avoid at source; minimise at source; abate on site; abate at receptor; repair; compensate in kind; compensate by other means. |
| Monitoring | can refer to a process of checking for compliance to conditions of consent for a planned intervention to go ahead, but typically refers to the process of ongoing testing to determine that there are no unanticipated impacts. |
| Moral outrage | anger provoked by the perception or belief that some moral standard, such as a standard of fairness or justice, has been violated. |
| Multiplier effect | (see Regional multiplier) |
| Naming and shaming | a strategy that attempts to build commitment or compliance to expected norms and/or good practice by publicising the names of wrong-doers or offenders. It is often contrasted with 'knowing and showing'. |

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| Needs assessment | a systematic procedure for determining client or community issues and ranking of importance as a component of program development. Needs assessment is the forerunner of modern day public involvement programs. |
| Newcomers | new residents in a particular location. |
| NIMBY | an acronym that stands for 'Not In My BackYard'. It refers to the reaction often obtained when considering the siting of locally-unwanted landuses (LULUs) like airports, landfill sites, windfarms, etc. |
| Non-technical risks | relate to the managerial, legal, social and political aspects of a project. In industry thinking, they are sometimes regarded as being 'external' risks (or even 'above ground'), as they are considered to occur as a result of circumstances outside the control of the project managers. |
| Normalisation | the attempt to avoid the development of a company town or a boomtown ethos, or to convert a company town into a more normal community life. |
| Normative | a normative perspective or judgement means the making of claims about how things should or ought to be, how to value them, which things are good or bad, and which actions are right or wrong; usually by reference to an ethical principle, or arguably by reference to an international code or standard that is beyond the legal requirements (if it was legally-required, it would not be a normative requirement). |
| Oldtimers | a colloquial expression referring to the long-term residents of a location, used in contrast to the newcomers. The interests of oldtimers are often different to those of newcomers. |
| Outcomes | in evaluation, program logic and project management, outcomes are the higher-order goals and objectives of the program. |
| Outputs | in evaluation, program logic and project management, outputs refers to the products of the program. The important concept is that outputs are rarely the intended outcomes, they are merely a stepping stone to achieve the outcomes. |
| PAPs | (see Project affected people) |
| Paradigm | the set of practices, methods, theories and understandings that held by a scientific discipline (and thus define it) at a particular period of time. In other words, the worldview of a field of research, i.e. what the body of scholars and practitioners in a particular field of enquiry consider to be current good practice. |
| Participation | a process through which stakeholders influence and share control over development initiatives and the decisions and resources which affect them. It is a process which can improve the quality, effectiveness and sustainability of projects and strengthen ownership and commitment of government and stakeholders. |
| Participation Agreement | (see Impacts & Benefits Agreement) |
| Participatory monitoring | the involvement of stakeholders in monitoring activities and the verification of information to ensure the legitimacy of the monitoring process and the project as a whole. |
| Perceived impact | something that is believed to be a potential impact rather than something that has been established as being an actual impact. Note that perceived impacts affect how people feel about the project and how they feel and behave generally, thus perception is reality for them. |

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| Performance standards | a performance standard is a generic concept that articulates the expected standard of practice or achievement. In an SIA context, it typically refers to the International Finance Corporation's Performance Standards for Environmental and Social Sustainability. |
| Permitting process | the regulatory process of assessing and approving a project. (also see Environmental licence) |
| Physical displacement | (see Displacement) |
| PIMBY | please in my backyard. The opposite of NIMBY, this is a way of thinking about gaining a social licence to operate so that people would be welcome to projects occurring nearby. |
| Place | geographical space that has been given meaning (negative as well as positive sentiment) because of the personal experiences and/or relationships to it by individuals or groups. |
| Place attachment | the extent to which an individual has positive feelings about their local environment and/or community. |
| Place dependency | similar to place attachment but used to emphasise the extent to which a person is dependent on, or tied to, a particular location, and therefore unable to move, and thus somewhat vulnerable to changes. |
| Placelessness | can refer either to locations that lack a 'spirit of place', are unauthentic or disconnected from their environmental setting; OR it can refer to the disconnectedness that individuals feel as a result of having been resettled or because of the rate of change in their community. |
| Plan | a strategy to achieve identified objectives and/or an implementation agenda. |
| Planned intervention | a project, plan, policy or program. Basically any considered action that seeks to achieve a defined outcome or goal. |
| Policy | a document prepared by an organisation that is a statement of principle, or an overarching statement of goals or procedural steps, about some matter of organisational significance. |
| Post-closure planning | (see Closure planning) |
| Potential impact | an impact that is predicted, rather than an actual impact that has already occurred. |
| Prediction | the task of identifying likely future impacts for a specific planned intervention. |
| Primary zone of influence | refers to the social impacts that occur in the primary zone of influence by the proposed action and occur in the same time and place. |
| Profanisation | the process by which sacred objects become ordinary (profane). Exposure to other cultures, and especially the sale of cultural artefacts, leads to them losing their sacred value. |
| Profiling | the process of collecting background information on the characteristics of a community and the local environment in the pre-development state. |
| Program | a coherent, organised agenda or schedule of commitments, proposals, instruments and/or activities that elaborates and implements policy, eventually comprising several projects. |

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| Project | a proposed capital undertaking, typically involving the planning, design and implementation of specified activities. |
| Project affected person/ persons/people (PAPs) | a World Bank/IFC term that can sometimes mean anyone who is negatively affected by a project, but can sometimes refer primarily to people who need to be resettled or are otherwise displaced as a result of the project. |
| Project area of influence | includes: the primary project site(s) and related facilities that a proponent (or its contractors) develops or controls; associated facilities that are developed as a result of the project (even if not directly funded by the project but funded by a client or a third party including the government), and whose viability and existence depend exclusively on the project and whose goods or services are essential for the successful operation of the project; areas potentially impacted by cumulative impacts from further planned development of the project; and areas potentially affected by impacts from unplanned but predictable developments caused by the project that may occur later or at a different location. |
| Project-induced in-migration | (see Honeypot effect) |
| Projection | in an SIA context, projections refer to the estimations/extrapolations/predictions/ forecasts about the future state of one or more social impact variables being considered. |
| Proponent | the organisation (government, commercial or NGO) or individual which seeks to commence a particular project. In regulatory terms, usually refers to the organisation or individual that submitted the Development Application or Notification of Intent. |
| Public comment period | in regulatory impact assessment processes, there is usually a requirement that the completed Impact Statement is available to the public for their comment for a designated period of time (e.g. 30, 45, 60 or 90 days). |
| Public Consultation, Public Involvement, Public Participation and Community Engagement | although often used interchangeably, there are important distinctions. Arguably '*public involvement'* is an over-arching concept relating to the processes of involving the public in decision-making processes. *'Consultation'* implies the seeking of the views of the community, whereas *'participation'* implies actually bringing the public into the decision-making process. |
| Quality of life | the general wellbeing of an individual, differing from standard of living in that it includes all the subjective, non-economic dimensions of life. |
| Regional multiplier | an economics term that refers to the ratio of the size of the final total economic effect on a regional economy of a specific initial stimulus (such a project) relative to the size of the direct impact; the extent to which local investment is amplified in a local economy. |
| Regulatory agency | (regulator, regulatory authority, regulatory body, competent authority) is a public authority or government agency responsible for exercising decision making and oversight over some area of human activity in a regulatory or supervisory capacity. In an SIA context, this may be the Department of Environment or the Department of Planning. The agency is responsible for determining the acceptability of an Environmental Impact Statement or Social Impact Assessment report and for issuing the licence to proceed with the project. |
| Rehabilitation | in impact assessment, this generally refers to restoring the landscape to how it was before the project (restoration), or where this is not possible at least to making the landscape acceptable to people (remediation). In mining, for example, it refers to replacing the soil layers and re-vegetating the land. |

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| Replacement cost | an economics and insurance concept that refers to the full cost of replacing an asset. The valuation for compensation purposes of assets destroyed by a project can be controversial. Insurance assessors often use the depreciated value of an asset. In project-induced resettlement and displacement, full replacement cost should be provided to ensure that people are not made worse off. |
| Reputational risk | (or reputational harm) the potential risk to the reputation of an organisation by associating or being associated with a particular practice. |
| Resettlement | the planned process of relocating people and communities from one location to another as part of the project-induced land acquisition necessary to allow a project to proceed. Resettlement is regarded as involuntary when the location of the project is fixed and local communities have, in effect, no choice but to be resettled; whereas resettlement is regarded as voluntary when no state power of eminent domain is used, threatened, or perceived to be threatened, and the individuals affected do have a real choice about whether they will agree to be resettled or not. |
| Resettlement Action Plan (RAP) | developed in line with the project's Resettlement Policy Framework, the RAP is a detailed strategy as to how a specific resettlement process will actually be conducted. The RAP details the processes of recording baseline conditions, consulting affected people, and provides a detailed strategy for: (i) minimizing or avoiding resettlement; (ii) compensating for losses; (iii) relocating and rebuilding as necessary; (iv) ensuring that affected people are afforded the opportunity to improve the incomes, income-producing activities, and standards of living that they had before the project affected them. |
| Resettlement Policy Framework (RPF) | a policy or operational guideline for the project about how issues of land acquisition, resettlement, compensation and livelihood restoration will be addressed throughout the project. |
| Residual impact | the predicted adverse impacts which remain even after mitigation measured have been implemented. |
| Resilience | capacity of a community to recover from impacts that threaten it. |
| Resistance | the capacity of a community to resist change, to be able to fight back against undue development. |
| Rights-based approach | (see Human rights-based approach) |
| Rights holder | individuals and groups whose rights have been impacted. Arguably they include all stakeholders. The term is in effect similar to stakeholder but the use of 'rights holder' implies a connection to the human rights-based approach and a pointed awareness that these people may have a legal standing. |
| Risk | can mean the probability of an event occurring; but the term can be used with a slightly different meaning to refer to an uncertain event (of unknown probability) that, if it occurs, will affect achievement of one or more objectives. Sub-categories of risk are often created. For example, non-technical risks (or social risks) relate to the managerial, legal, social and political issues of a project; whereas the technical risks are the physical, structural, engineering and environmental aspects. |
| Rite/ritual | a ceremonial act that is an expression of culture and community. |
| Rootedness | being strongly embedded in the local community – like a tree having roots. A component of place attachment, alongside sense of place, rootedness refers to a person's social links (social capital) to others in the community, for example, having local relatives, having long-term friends, having close friends, etc. |

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| Royalty | in general terms, a royalty is a payment made by one party (the licensee) to another (the licensor) for the right to the ongoing use of an asset. In an SIA context, royalties are payments made by resource extraction companies to governments and/or traditional owners of land for their access to the resources extracted. |
| Sabotage | a deliberate act intended to harm a corporation through obstruction, disruption, or destruction. Aggrieved stakeholders may take direct action against a project by blockading the project, or by destroying equipment either in an attempt to attract publicity, retard the project, or simply as an act of revenge. |
| Sacred | having spiritual or religious significance. |
| Sacred site | a site (location in a landscape) of special spiritual significance to the local people. Although usually associated with Indigenous peoples, arguably it can apply more broadly to refer to other spiritual and religious sites and shrines of high cultural heritage significance. |
| Safeguard policies | a suite of policies of the World Bank that stipulate environmental and social performance. |
| Scoping | the process of determining the main issues of concern and the interested affected parties for a particular planned intervention. |
| Screening | a selection process to determine whether an impact assessment is required and, if so, what type of impact assessment should be done. In a regulatory environment, this is specified in the applicable regulations. Although the term is not always used in this way, arguably 'screening' can apply more generally to refer to determining the requirements that need to be met, or procedures that need to be followed, that are implied in company procedures, national and international legislation, and/or the requirements of financial partners, especially when World Bank, IFC, or Equator Principles banks might be involved. |
| Self-determination | one of the designated human rights that pertains to groups (rather than individuals) and which establishes that all peoples should be able to freely determine their political status and freely pursue their economic, social and cultural development. |
| Sense of community | (see Community mindedness) |
| Sense of place | an individual's personal relationship with their local environment, both social and natural, which the individual experiences in their everyday daily life. |
| Shared infrastructure | refers to infrastructure built for the project but which is also made available to service local community needs. It can refer to electricity generation, water supply, sewerage treatment, as well as to bridges, roads, railway lines, ports and airports. |
| Shared value | a way of thinking about the role of a company that recognizes that societal needs, not just conventional economic needs, define markets, and that the purpose of the corporation must be defined as creating shared value not just profit, so society benefits as well as the company. This view also acknowledges that social harms frequently create costs for firms in the form of social risks and therefore need to be carefully managed. |
| Significance (assessment, determination) | the act of assigning some form of prioritisation to the issues to be considered for further analysis and/or mitigation. Following the scoping process, the impacts are assessed for their significance according to some predetermined criteria or in a deliberative process with a community liaison committee. |
| SIMP | Social Impact Management Plan |

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| SME | small to medium enterprise, defined differently in different countries using number of employees and/or annual revenue criteria. When sole operator or very small enterprises are exclusively intended, 'micro enterprise' is the term used. SMEs are important in SIA because they are often disperse, unorganised, and very often affected by projects. With care, they can also be significantly positively involved by a commitment to local procurement. |
| Social area of influence | a term that means much the same as 'area of influence' but that emphasises the social impacts of the project. Because of the mobility of people and the extent of social impacts, the social area of influence is likely to be much larger in physical area than the physical area of influence. |
| Social baseline | (see Baseline) |
| Social carrying capacity | refers to the numbers of people a particular location can support. While (ecological) carrying capacity is a fairly establish term in ecology, the social carrying capacity is a term seldom used by social scientists. Park managers talk about social carrying capacity as the number of tourists they think their park can accommodate, and in the tourism field, there is a notion about social carrying capacity as the number of tourists that a particular tourism attraction (site, village, region, culture) can comfortably cope with. |
| Social capital | the social resources upon which people draw in pursuit of their livelihood objectives including their networks and connectedness, and their relationships of trust, reciprocity and exchanges that facilitate cooperation, reduce transaction costs, and provide the basis for informal safety nets. It includes the institutions, relationships, attitudes, values and shared values and rules for social conduct that govern interactions among people and contribute to economic and social development. |
| Social change process | an identifiable process of change in project-affected communities that is created, initiated, enabled, facilitated and/or exacerbated by a planned intervention. The social change process is not in itself a social impact, but may or may not result in the experience of social impacts depending on the local context. For example, in-migration and resettlement are social change processes that may or may not result social impacts. |
| Social determinants of health | the economic and social conditions, and their distribution in a population, that influence individual and group differences in health status. It refers to the social risk factors in a person's living and working conditions rather than to the individual factors (such as behavioural risk factors or genetics) that influence the risk of disease, or vulnerability to disease or injury. The distributions of social determinants are shaped by public health and other policies, poor governance, and unfair economic arrangements where the already well-off and healthy become even better off while the poor who are already more likely to be ill become even poorer. |
| Social development | in SIA, social development refers to the process of progressing towards the desired development goals for a particular society. It is a process of planned social change and goes hand-in-hand with economic development. The social development goals will vary between locations depending on the local context, but could be about enhancing wellbeing and/or economic prosperity, improving sustainable livelihoods, improving the provision of basic services in a society such as health and education, enhancing social inclusion, building capacity, enhancing good governance, etc. Social development is largely similar to community development but with a greater emphasis of achieving development outcomes. |
| Social development outcomes | refers to the results a particular development intervention is expected to achieve. |

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| Social disarticulation | the process by which the social networks and support mechanisms within a social group are disrupted. It often happens as a result of the fragmentation that occurs through resettlement. |
| Social disintegration | the process of the breaking down of social order in a community. |
| Social diversity | refers to the localised mix of social groups and individuals based on characteristics such as gender, ethnicity, age, culture and economic background. |
| Social exclusion | the processes that retard the achievement of social inclusion and social integration, and/or that lead to the marginalisation of vulnerable groups. |
| Social footprint | a concept which attempts to be the social equivalent of 'ecological footprint', thus a metaphor referring to the extent of social harm created by a project or product. It is a concept not favoured by social scientists and thus not used in SIA, but some physical scientists promote this concept alongside the ecological footprint. |
| Social fund | the provision of funding (perhaps but not necessarily as compensation) from a project to be directed towards impacted peoples. Social funds are usually managed by the community and are intended to be for the furtherance of social projects the benefit the community as a whole. They are often calculated as percentage of something, such as dollar per Megawatt Hour of electricity produced, or kilotonne of ore extracted from a mine. A social fund is not a royalty payment, although royalty payments may also be paid into social funds. |
| Social impact | something that is experienced or felt, in a perceptual or corporeal sense at the level of an individual, social unit (family/household/collectivity) or community/society. (also see Social change process) |
| Social Impact Assessment (long form) | includes the processes of analysing, monitoring and managing the intended and unintended social consequences, both positive and negative, of planned interventions (policies, programs, plans, projects) and any social change processes invoked by those interventions. Its primary purpose is to bring about a more sustainable and equitable biophysical and human environment. |
| Social Impact Assessment (short form) | analysing, monitoring and managing the social consequences of development. |
| Social Impact Management Plan (SIMP) | a formal document and associated management system that outlines the strategies to be undertaken during the various phases of a development (including closure) to monitor, report, evaluate, review and proactively respond to change. Somewhat similar to a Social Impact Statement, the idea behind a SIMP is to focus on the management strategies to address the impacts rather than just being a listing of potential impacts. |
| Social Impact Statement | the SIA version of an Environmental Impact Statement; a formal document submitted to a regulator. |
| Social inclusion | a social justice concept that refers to a policy commitment and the active strategies by government at all levels and civil society to enhance the access of diverse individuals and groups to development opportunities and to full participation in society through the removal of institutional constraints to participation and the provision of incentives and mechanisms for participation. |
| Social indicator | a statistical measure (variable) used to monitor change in social phenomenon. In SIA, social indicators are identified for all of the social issues identified as being important topics to monitor. |



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| Social innovation | a discourse around new ways in meeting the social needs of, or delivering social benefits to, communities through the redesign of and/or creation of new, products, services, organizational structures, governance structures, policies, procedures and activities that are more effective than existing traditional public sector, philanthropic and market-reliant approaches in responding to social exclusion. |
| Social integration | the ability of different groups in society to live together in productive and cooperative harmony and to accommodate differences within a framework of common interest to the benefit of all. Social integration implies justice for the individual and harmony among different social groups and countries. It means integration of disadvantaged and vulnerable groups by making all institutions of society more accessible to them. |
| Social investment | in SIA, social investment refers to the idea that a project should make a contribution to local development by making funding available for projects that contribute to local development outcomes. Strategic social investment is used when there is a clear business case to the company making the funds available. |
| Social justice | refers to notions of fairness and equity across a society. It is a philosophy about respect for human rights, the notion that everyone should have the chance to improve themselves, and that they should have the opportunity to participate in decisions affecting their own life. |
| Social licence to operate | a popular expression to imply that the acceptance of the community is also necessary for a project to be successful. |
| Social licence to operate and grow | a variant on 'social licence to operate' which emphasizes that the acceptance of all stakeholders is also necessary for the business to expand. |
| Social management system | a management system that specifically addresses the management of social issues in a company/project. |
| Social performance | the interface between a project and society; a business organization's configuration of principles of social responsibility, processes of social responsiveness, and policies, programs, and observable outcomes as they relate to the firm's societal relationships. |
| Social profile | (see Community profile) |
| Social return on investment (SROI) | is a method for measuring the additional benefit beyond immediate financial return of investments in projects or activities, for example of social investment funding. It is usually express as a ratio relative to resources invested. |
| Social risk | the World Bank defines social risk as "the possibility that the intervention would create, reinforce or deepen inequity and/or social conflict, or that the attitudes and actions of key stakeholders may subvert the achievement of the development objective, or that the development objective, or means to achieve it, lack ownership among key stakeholders. Such risks may arise out of the country's socio-cultural, political, operational or institutional context." |
| Socially-responsible security | an approach to security services around a project that pays attention to human rights and other social issues; and likely to be consistent with the Voluntary Principles on Security and Human Rights. |
| Soft regulation | (or 'soft law') refers to the informal processes of control over the activities of a company such as industry standards and guidelines. It also refers to global agreements, covenants, etc that influence the practices of companies and how they are judged or perceived. |

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| Spirit of place | refers to the unique, distinctive and cherished aspects of a place. Whereas 'sense of place' is the personal feelings an individual has about a place, spirit of place refers the inherent characteristics of the place. |
| Stakeholders | include all individuals and groups who are affected by, or can affect, a given operation. Stakeholders consist of individuals, interest groups, and organizations. |
| Stakeholder analysis | a deliberate process of identifying all stakeholders of a project (i.e. the individuals and groups that are likely to impact or be impacted by it) and understanding their concerns about the project and/or relationship with it. |
| Standard | a norm, convention or ruling that is used as a benchmark or target. |
| Standard of living | the physical, objective indicators of the wellbeing of an individual or group. |
| Strategic social investment | social investment that is specifically designed to meet both the strategic aims of the project/company and the needs and aspirations of the local communities. |
| Subjective wellbeing | the personal experience of one's life, the level of satisfaction with one's life; how happy people feel in general terms about their life as a whole. |
| Subsistence | an adjective applied to a range of words such as the subsistence economy, subsistence livelihoods, subsistence farming, subsistence fishing, and subsistence mining (i.e. artisanal mining). Subsistence refers to the informal or non-market economy (rather than to the cash economy) in which people produce their own goods and services, or exchange them in barter arrangements rather than for cash. |
| Sustainable development | the Brundtland Commission's report, *Our Common Future,* defines sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. |
| Sustainable livelihood | a livelihood comprises the capabilities, assets (see Capitals) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base. |
| Sustainable Livelihoods Approach (or framework) | is a way of analysing the effect of projects on the livelihoods of people and communities. It uses the capitals (livelihood assets) as the basis of the framework. |
| SWOT analysis | an analysis that considers the strengths, weaknesses, opportunities and threats of an organisation or community. |
| Taboo | something that is culturally forbidden. Projects often violate taboos in ignorance creating much offence. |
| Technocratic | a pejorative term that refers to people and institutions that have excellent technical skills but lack social awareness and social understanding; and in particular who make decisions on the basis of their technical knowledge without due consideration of the social and political context. |
| Traditional knowledge | (see Local knowledge) |
| Traditional owners | a term used in Australia to refer to Indigenous people who have a valid claim to be regarded as the land owner under native title. |
| Transboundary impacts | refers to the impacts, environmental and social, that transfer across boundaries, typically national boundaries, but arguably across any jurisdictional boundary. |
| Values | abstract and often subconscious assumptions held by individuals about what is right and/or important in their lives. Typically they are organised into a value system. Values and value systems can vary substantially between cultural groups. |

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| Venting | the process of 'letting off steam'. In SIA this refers to situations where people who are angry or emotional can express their feelings. Opportunities to vent are a necessary part of a good community engagement process. |
| Vernacular heritage | the word 'vernacular' typically refers to the everyday language of ordinary people in a specific location. Similarly, 'vernacular heritage' refers to the cultural heritage that pertains to ordinary people's lives or that is specific to small groups of people with a common language and/or set of experiences. |
| Voluntary Principles | within SIA generally refers to the Voluntary Principles on Security and Human Rights. |
| Voluntary resettlement | (see Resettlement) |
| Vulnerability | a situation or condition characterized by low resilience and/or higher risk and reduced ability of an individual, group or community to cope with shock or negative impacts. Vulnerability is associated with having low socio-economic status, disability, ethnicity, or one or more of the many factors that influence people's ability to access resources and development opportunities. |
| Vulnerable groups | groups which a characterised by having vulnerability. Although vulnerability is context-dependent and can include a very wide range of groups, typically the concept includes: Indigenous peoples, ethnic minorities, migrants, disabled people, the homeless, the poor, those struggling with substance abuse, and isolated elderly people. |
| Watchdog NGO | a non-government organisation (NGO) whose mission or objectives especially include a monitoring role to oversee the activities of companies or other organisations. Watchdog NGOs tend to 'name and shame' as their strategy to encourage better industry practice. |
| Weekenders | refers to people who live elsewhere who come to their second home for weekends and holidays. Sometimes the term is also used to refer to the houses. They are often an important element in SIAs, but are often hard to access. They are sometimes negatively affected by projects, and/or have different issues to other people in the affected community. |
| Wellbeing | the social, economic, psychological, spiritual or medical state of an individual or group. |
| White elephant | a commonly used expression that nowadays refers to a facility (building, etc) of high cost and limited usefulness. Historically, the word had a more precise meaning relating to a crippling maintenance cost (an asset that is a liability) but also to an inability to dispose of it. Unless care in taken in the selection of social investment expenditure, many projects can be white elephants. |
| World Bank safeguard policies | refers to the set of 10 Operational Policies that have been identified by the World Bank as being important in ensuring that their operations do not harm people or the environment: Environmental Assessment (OP 4.01); Disputed Areas (OP 7.60); Forests (OP 4.36); Indigenous Peoples (OP 4.10); International Waterways (OP 7.50); Involuntary Resettlement (OP 4.12); Natural Habitats (OP 4.04); Pest Management (OP 4.09); Physical Cultural Resources (OP 4.11); and Safety of Dams (OP 4.37). |
| World Bank social safeguard policies | refers to a subset of safeguard policies (see above) that are specifically about social issues (or that are managed by the Bank's Social Development Department) including: Indigenous Peoples (OP 4.10) and Involuntary Resettlement (OP 4.12). |
| Worldview | the perspective by which a person (and sometimes a society or culture) views their world; in other words, a cognitive framework. It's a term frequently used by social scientists and SIA practitioners. |

IAIA

International Association for Impact Assessment

International Headquarters, 1330 23rd Street South, Fargo, ND 58103 USA
Phone: +1-701-297.7908
Fax: +1-701-297.7917
E-mail: **info@iaia.org**
Website: **http://www.iaia.org**

Suggested reference format: Vanclay, F., Esteves, A.M., Aucamp, I. & Franks, D. 2015 *Social Impact Assessment: Guidance for assessing and managing the social impacts of projects.* Fargo ND: International Association for Impact Assessment.



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4-1) Referring to Crowned Ridge's response to Staff data request 3-3, please provide the following:

i) An explanation as to why section 3 of the Sound Study (Appendix H to the Application) did not identify that Dakota Range I&II was included in the noise model,

**Response**: The Sound Study filed with the Application did not include the effects from the Dakota Range I & II wind project, as the Study focused on the sound resulting for the proposed Crowned Ridge Wind project. Subsequently, the effects of the Dakota Range I and II project were set forth on page 4 of Haley's Supplemental testimony.

ii) An explanation as to why the sound pressure contours in Appendix D of the Sound Study do not appear to factor in the noise levels of the Dakota Range I & II wind turbines; and

**Response:** The sound pressure contours in Appendix D submitted with the Application only showed the effects of the proposed Crowned Ridge Wind project, as it focused on the effect from the proposed project. The results tables in the Sounds Study, however, did include the effects of all Dakota Range I and II and Crowned Ridge Wind II wind turbines.

iii) Provide updated Standard Resolution Sound Maps as found in Appendix D of the Sound Study that includes on the map the Dakota Range I & II wind turbines that influence sound levels for receptors studied in the Crowned Ridge Project.

**Response:** Attached are updated maps that include rge iso-lines for both Dakota Range Wind I and II and Crowned Ridge Wind II turbines within 2 kilometers of Crowned Ridge Wind receptors.

**Respondent:** Jay Haley, Wind Engineer

EXHIBIT
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Jay Haley, PE

Partner

## Project Assignment

Mechanical Engineer, Wind Engineering Consultant

## Registrations

Registered Mechanical Engineer - North Dakota, Minnesota

## Educational Background

| | |
|---|---|
| 1985: | Bachelor of Science, Mechanical Engineering<br>University of North Dakota, Grand Forks, ND |

## Work History

| | |
|---|---|
| 2000-Present: | Mechanical Engineer/Partner, EAPC, Grand Forks, ND |
| 1998-2000: | Mechanical Engineer, EAPC, Grand Forks, ND |
| 1989-1998: | Senior Design Engineer, Energy and Environmental Research Center, Grand Forks, ND |
| 1985-1989: | Director of Engineering, Ideal Aerosmith, Inc., East Grand Forks, MN |

## Professional Experience

Mr. Haley has been involved in wind energy since 1983. He's performed or supervised the wind resource assessments and energy assessments for hundreds of projects totaling more than 40,000 MW, of which, more than 8,000 MW are currently in operation. He has also provided Independent Engineering reviews of other consultant's wind assessment reports for various potential investors on 50+ projects totaling more than 5,000 MW.

He is also a certified WAsP user as well as a WindPRO training instructor, and has conducted more than 40 training courses and trained more than 500 wind industry personnel in the proper use of WindPRO and WAsP as it relates to wind resource and energy assessment and site suitability.

He's been involved in the planning, permitting, design, construction, and operation of wind farms. He's made hundreds of public presentations on wind energy and has been the wind industry's primary spokesperson in ND. Mr. Haley has been a member of the National Wind Coordinating Committee, the North Dakota Wind Coordinating Committee, Co-Chair of the Energy Cluster of ND's New Economy Initiative, Vice-Chairman of the ND Renewable Energy Partnership, Founding Executive Board member of the ND SEED Coalition, a member of U.S. Senator Dorgan's wind conference planning committee, and is also the founding Chairman of the Wind Energy Council, a regional trade organization in the upper Midwest.

Mr. Haley is an appointed technical expert representing the U.S. delegation on the International Standards Committee IEC 61400-15 - *Assessment of Wind Resource, Energy Yield and Site Suitability Input Conditions for Wind Power Plants.*

EXHIBIT
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## Relevant Experience – Wind Resource and Energy Assessment and Wind Farm Design – Selected Projects

2018 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, YPF Energía Eléctrica S.A., Fray Guen Wind Farm, 100 MW

2018 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Eólica Rionegrina S.A., PE Cerro Policia Wind Farm, 600 MW

2018 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Sequoia Energy, Assiniboia Wind Farm, 200MW

2018 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Allete Clean Energy, South Peak Wind Farm, 100 MW

2017 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Allete Clean Energy, Bowman Wind Farm, 208 MW

2017 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Allete Clean Energy, Top of Iowa Repower, 80 MW

2017 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Allete Clean Energy, Storm Lake I Repower, 309 MW

2016 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, TradeWind Energy, Cedar Run Wind Farm, 200 MW

2016 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, TradeWind Energy, Seven Cowboy Wind Farm, 300 MW

2016 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Minnesota Power, Tri County South Wind Farm, 104 MW

2015 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Bluestem Energy, West Liberty Wind Farm, 4 MW

2015 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, AV3 WindPower, Green Hills Wind Farm, 60 MW

2015 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, TradeWind Energy, Lindahl West, 300 MW

2015 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, TradeWind Energy, Thunder Ranch Wind Farm, 300 MW

2014 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Allete Clean Energy, Chanarambie/Viking Repower, 97 MW

2014 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, TradeWind Energy, Rose Rock, 108 MW

2014 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, NRG Patagonia, Valle Hermosa, 12 MW

2013 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Allete Clean Energy, Clean Energy I Wind Farm, 102.4 MW

2013 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Minnesota Power, Bison IV Wind Farm, 204.8 MW

2012 - Wind Resource and Energy Assessment, Project Resources Corp., Lakeswind Wind Farm, 50 MW

2011 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Minnesota Power, Bison III Wind Farm, 105 MW

2011 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Minnesota Power, Bison II Wind Farm, 105 MW

2010 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Basin Electric, PrairieWinds SD I Wind Farm, 162 MW

2010 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Minnesota Power, Bison IB Wind Farm, 45 MW

2010 - Wind Resource and Energy Assessment, Site Suitability, Wind Farm Design, and CFD Analysis, PowerWorks, Sawtooth Wind Farm, 22.4 MW

2009 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Minnesota Power, Bison IA Wind Farm, 36.9 MW

2008 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Basin Electric, PrairieWinds ND I Wind Farm, 115.5 MW

2006 – Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, Trimont Area Wind Farm, TAWF-II, 100.5 MW

2004 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, PPM Energy, Rugby Wind Farm, 150 MW

2003 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, FPL Energy, ND Wind I & II, 61.5 MW

2003 - Wind Resource and Energy Assessment, Site Suitability and Wind Farm Design, FPL Energy, SD Wind Energy Center, 40.5 MW

## Relevant Experience – Noise and Shadow Flicker Studies – Selected Projects

2018 – Noise and Shadow Flicker Studies, Terra-Gen, TG High Prairie Wind Farm, LLC, 387.4MW

2018 – Noise and Shadow Flicker Studies, Project Resources Corp., Red Barn, LLC, 129.5 MW

2018 – Shadow Flicker Study, Geronimo Energy, Blazing Star Wind Farm, 200MW

2017 – Noise Study, Project Resources Corp., Lakeswind Wind Farm, 50 MW

2017 – Shadow Flicker Study, Capital Power, Black Fork Wind Farm, 200 MW

2017 – Shadow Flicker Study, Tenaska, Inc., Nobles 2 Wind Farm, 250 MW

2017 – Noise and Shadow Flicker Studies, Invenergy, Freeborn Wind Farm, 100MW

2017 – Shadow Flicker Study, Geronimo Energy, Blazing Star II Wind Farm, 200MW

2016 – Noise Study, Project Resources Group, Rock Aetna Wind Farm, 24 MW

2016 – Shadow Flicker Study, Orion Renewable Energy Group, Jordan Creek Wind Farm, 298 MW

2016 – Shadow Flicker Study, Geronimo Energy, Blazing Star Wind Farm, 200 MW

2016 – Shadow Flicker Study, Tenaska, Inc., Nobles 2 Wind Farm, 250 MW

2016 - Noise and Shadow Flicker Studies, Orion Renewable Energy Group, Charlie Creek Wind Farm, 271 MW

2016 – Noise and Shadow Flicker Studies, EDF Renewables, Red Pine Wind Farm, 200 MW

2016 – Shadow Flicker Study, TradeWind Energy, Cedar Run Wind Farm, 200 MW

2016 - Noise and Shadow Flicker Studies, Minnesota Power, Tri-County South Wind Farm, 104 MW

2016 – Shadow Flicker Study, Starwood Energy Group, Trishe Wind Energy Project, 115 MW

2016 – Noise and Shadow Flicker Studies, TradeWind Energy, Alta Farms II Wind Farm, 200 MW

2015 – Noise and Shadow Flicker Studies, Bluestem Energy, West Liberty Wind Farm, 4 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Chisholm II Expansion, 65 MW

2015 – Noise and Shadow Flicker Studies, AV3 WindPower, Green Hills Wind Farm, 60 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Lindahl West Wind Farm, 300 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Limestone Bluff Wind Farm, 356 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Red Dirt Wind Farm, 300 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Hallam NE Volkswind, 200 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Blue Star Wind Farm, 150 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Wild Plains Wind Farm, 300 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Diamond Vista Wind Farm, 300 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Armadillo Flats Wind Farm, 235 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Thunder Ranch Wind Farm, 300 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Sundance Wind Farm, 200 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Cimarron Bend Wind Farm, 200 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Rock Creek Wind Farm, 300 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, English Farms Wind Farm, 170 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Sunwind Doyle Wind Farm, 200 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, NorthStar and RedRock Wind Farms, 500 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Emmons-Logan Wind Project, 304 MW

2015 – Noise and Shadow Flicker Studies, TradeWind Energy, Butler Wind Farm, 150 MW

### Relevant Experience – Due Diligence – Select Projects

2016 - Independent Review of Energy Assessment and Existing Production, TradeWind Energy, Seven Cowboy, 300 MW

2016 - Independent Review of Energy Assessment and Existing Production, TradeWind Energy, Alta Farms II, 200 MW

2015 - Independent Review of Energy Assessment and Existing Production, TradeWind Energy, NorthStar and RedRock, 500 MW

2015 - Independent Review of Energy Assessment and Existing Production, TradeWind Energy, Rock Creek Wind Farm, 300 MW

2015 - Independent Review of Energy Assessment and Existing Production, TradeWind Energy, Thunder Ranch Wind Farm, 300 MW

2014 - Independent Review of Energy Assessment and Existing Production, Allete Clean Energy, Chanarambie/Viking, 97 MW

2014 - Independent Review of Energy Assessment and Existing Production, Wind Energy Development, LLC, Picillo Wind Farm, 3 MW

2014 - Independent Review of Energy Assessment and Existing Production, TradeWind Energy, Breckenridge, 100 MW

2013 - Independent Review of Energy Assessment and Existing Production, Greycliff Energy, LLC, Greycliff Wind Farm, 20 MW

2013 - Independent Review of Energy Assessment and Existing Production, Allete Clean Energy, Armenia Wind Farm, 100.5 MW

2013 - Independent Review of Energy Assessment and Wind Turbine Site-Suitability, Sigma Energy Solutions, Clara, Brazil, 10.5 MW

2013 - Independent Review of Energy Assessment and Wind Turbine Site-Suitability, Sigma Energy Solutions & GE Energy Finance, Shilo Wind Farm, 150 MW

2013 - Independent Review of Energy Assessment and Wind Turbine Site-Suitability, Sigma Energy Solutions & Starwood Energy Group, Pattern Energy 10 project portfolio, 2000 MW

2010 - Independent Review of Energy Assessment and Wind Turbine Site-Suitability, Alliant Energy, Whispering Willow East Wind Farm, 200 MW

2009 - Independent Review of Energy Assessment and Wind Turbine Site-Suitability, Sigma Energy Solutions & AIG, RePower 6 project portfolio, 99 MW

2008 - Independent Review of Energy Assessment and Wind Turbine Site-Suitability, Sigma Energy Solutions & GE Energy Financial, Aeolus IV, 4 project portfolio, 488 MW

2007 - Independent Review of Energy Assessment and Wind Turbine Site-Suitability, Sigma Energy Solutions & GE Energy Financial, Aeolus III, 3 project portfolio, 319.5 MW

2006 - Independent Review of Energy Assessment and Wind Turbine Site-Suitability, Sigma Energy Solutions & GE Energy Financial, Desert Sky, 160.5 MW

2006 - Independent Review of Energy Assessment and Wind Turbine Site-Suitability, Sigma Energy Solutions & GE Energy Financial, Aeolus II, 3 project portfolio, 356 MW

2005 - Independent Review of Energy Assessment and Wind Turbine Site-Suitability, Sigma Energy Solutions & GE Energy Financial, Kumeyaay , 50 MW

2004 - Independent Review of Energy Assessment and Wind Turbine Site-Suitability, Nebraska Public Power District, Ainsworth Wind Farm, 59.4 MW

### Relevant Experience – Expert Testimony

2016 - Noise & Shadow Flicker Expert Testimony, Orion Renewable Energy Group, Charlie Creek Wind Farm Conditional Use Permit, Billings County Planning and Zoning Commissioner's Permit Hearing, Medora, ND

2016 - Shadow Flicker Expert Testimony, Orion Renewable Energy Group, Jordan Creek Wind Farm Conditional Use Permit, Warren County Board of Zoning Appeals, West Lebanon, IN

2015 - Noise & Shadow Flicker Expert Testimony, Sage Law Partners, Sand Canyon, Tehachapi, CA

2014 - Noise & Shadow Flicker Expert Testimony, TradeWind Energy, Lindahl Wind Farm Conditional Use Permit, Williams County Planning and Zoning Commissioner's Permit Hearing, Williston, ND

2012 – Ice Throw Risk Expert Testimony, Vorys, Sater, Seymour and Pease LLP, Element Power, Buckeye Wind Farm Certificate of Environmental Compatibility and Public Need, Ohio Power Siting Board Public Hearing, Columbus, OH

2011- Noise & Shadow Flicker Expert Testimony, enXco, Merricourt Wind Farm Siting Application to the North Dakota Public Service Commission, Public Hearing, Ashley, ND

2011 - Shadow Flicker & Ice Throw Risk Expert Testimony, Element Power, Black Fork Wind Farm, Certificate of Environmental Compatibility and Public Need, Ohio Power Siting Board Public Hearing, Columbus, OH

2009 - General Wind Expert Testimony, New Frontier I & II Wind Farm Conditional Use Permit, McHenry County Commissioners Permit Hearing, Towner, ND

2008 - General Wind Expert Testimony, Peak Wind, Opposing Next Era's Ashtabula Wind Farm Conditional Use Permit, Barnes County Commissioner's Permit Hearing, Valley City, ND

2007 - General Wind Expert Testimony, EcoEnergy, New Holstein Wind Farm, Calumet County Commissioners Permit Hearing, Chilton, WI

2005 - General Wind Expert Testimony, Boone Heritage Wind Farm Conditional Use Permit, Boone County Commissioners Permit Hearing, Belvidere, IL

2004 - General Wind Expert Testimony, Bureau Valley High School Conditional Use Permit, Bureau County Commissioners Permit Hearing, Springfield, IL

2003 - General Wind Expert Testimony, Acciona Conditional Use Permit, Velva Wind Farm, McHenry County Commissioner's Permit Hearing, Towner, ND

### Relevant Experience – Course Instructor

Dec-2013 WindPRO Advanced Course – Las Vegas, NV
Sept-2011 Wind Energy Workshop – Buenos Aires, AR
Jan-2011 WindPRO In-House Training, Clipper – Carpentaria, CA
Nov-2010 WindPRO Basic Course – Boston, MA
Nov-2010 WindPRO Advanced Course – Montreal, QB
Sept-2010 WindPRO Advanced Course – Oklahoma City, OK
May-2010 WindPRO Advanced Course – Dallas, TX
Nov-2009 WindPRO Basic Course – Boston, MA
Sept-2009 WindPRO Advanced Course – Minneapolis, MN
May-2009 WindPRO Advanced Course – Chicago, IL
Nov-2008 WindPRO In-House Training, DNV-GEC, Webinar
Nov-2008 WindPRO Basic Course – Boston, MA
Oct-2008 WindPRO In-House Training, MN Power – Duluth, MN
Sept-2008 WindPRO Advanced Course – Minneapolis, MN

Jun-2008 WindPRO Basic Course – Houston, TX
May-2008 WindPRO Basic Course – Toronto, ON
Feb-2008 WindPRO Basic Course – Austin, TX
Jan-2008 WindPRO Basic Course – Minneapolis, MN
Dec -2007 WindPRO In-House Training, Basin Electric – Bismarck, ND
Oct-2007 WindPRO Basic Course – Quebec City, QB
Sept-2007 WindPRO In-House Training, Clemson Univ. – Clemson, SC
Sept-2007 WindPRO Basic Course – Minneapolis, MN
Aug-2007 WindPRO In-House Course, TradeWind Energy – Lenexa, KS
Jul-2007 WindPRO Seminar – Boston, MA
Jun-2007 WindPRO Advanced Course – Los Angeles, CA
Jun-2007 WindPRO In-House Course, BP Alt. Energy – Oakland, CA
Mar-2007 WindPRO Basic Course – Grand Forks, ND
Jan-2007 WindPRO Basic Course – Boston, MA
Oct-2006 WindPRO Basic Course – Winnipeg, MB
Sept-2006 WindPRO Basic Course – Grand Forks, ND
Oct-2005 WindPRO Basic Course – Toronto, ON
Sept-2005 WindPRO Basic Course – Grand Forks, ND
May-2005 WindPRO Basic Course – Denver, CO
Mar-2005 WindPRO Basic Course – Grand Forks, ND
Oct 2004 WindPRO Basic Course – Montreal, QB
April-2004 WindPRO Basic Course – Chicago, IL
Sept-2003 WindPRO Basic Course – Grand Forks, ND
May-2003 WindPRO Basic Course – Austin, TX
Aug-2002 WindPRO Basic Course – Grand Forks, ND

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| PE | John Allen Haley | 3736 Manchester | The Colony | TX | 75056 | 9729291199 | 14014 | EC | 9/30/2020 | Active |



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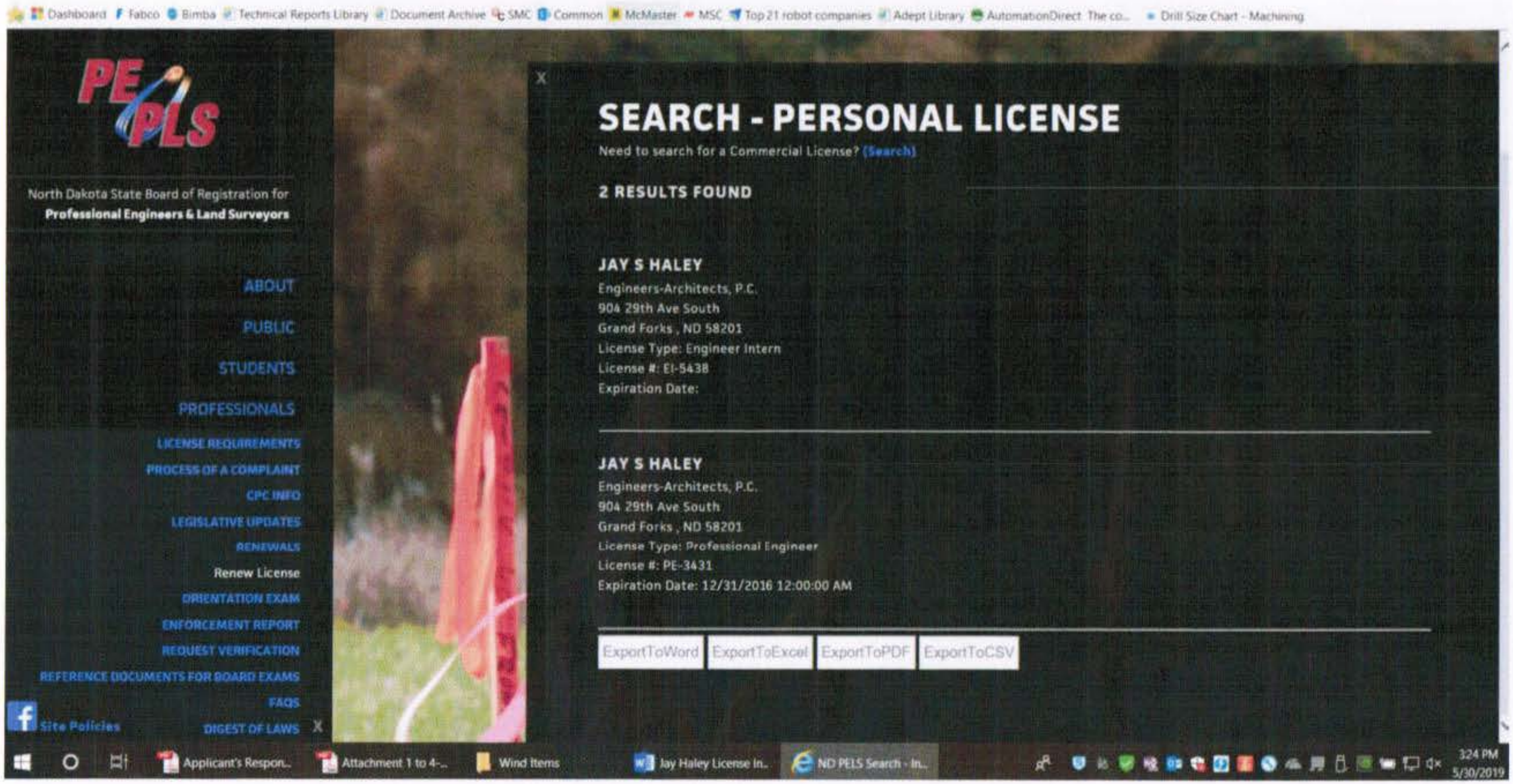

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**JAY S HALEY**
Engineers-Architects, P.C.
904 29th Ave South
Grand Forks , ND 58201
License Type: Engineer Intern
License #: EI-5438
Expiration Date:

---

**JAY S HALEY**
Engineers-Architects, P.C.
904 29th Ave South
Grand Forks , ND 58201
License Type: Professional Engineer
License #: PE-3431
Expiration Date: 12/31/2016 12:00:00 AM

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| Jay | S | Haley | Engineers-Architects, P.C. | 904 29th Ave South | Grand Forks | ND | 58201 | Professional Engineer | PE-3431 | 12/31/2016 12:00:00 AM |

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| License Holder Name | Lic # | Profession [Discipline] | When Granted | Expiration Date |
|---|---|---|---|---|
| Haley, Jay S | 25237 | Professional Engineer [Mechanical] | 4/7/1997 | EXPIRED |

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|---|---|---|---|---|
| Haley, Gregory T | 10808 | Architect | 2/28/1974 | 06/30/2020 |
| Haley, James Hollis | 19904 | Professional Engineer [Mechanical] | 7/19/1989 | EXPIRED |
| Haley, Jay S | 25237 | Professional Engineer [Mechanical] | 4/7/1997 | EXPIRED |
| | | Professional Engineer | | |

EXHIBIT

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MINNESOTA BOARD OF
ARCHITECTURE • ENGINEERING • LAND SURVEYING
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**Affidavit of Identification**

STATE OF MINNESOTA )
)
COUNTY OF RAMSEY )

Matt Kaehler, being first duly sworn on oath, deposes and states as follows:

1. This Affidavit is made in response to a request to produce confirmation of the status of Mr. Jay Haley's Minnesota professional engineer license.
2. I hereby confirm Mr. Haley was issued license number 25237 on April 7, 1997 and his license expired on June 30, 2016.
3. I am an Investigator for the Minnesota Board of Architecture, Engineering, Land Surveying, Landscape Architecture, Geoscience, and Interior Design (AELSLAGID), a custodian of the records of the Board, and I have first-hand knowledge of the above-captioned matter.

FURTHER YOUR AFFIANT SAYETH NOT.

Dated: May 29th, 2019

Matt Kaehler
Investigator
Minnesota Board of AELSLAGID
85 East Seventh Place, Suite 160
Saint Paul, Minnesota 55101

Sworn and subscribed to before me on this

29th day of May, 2019.

Victoria E Oehrlein
Notary Public

VICTORIA ELIZABETH OEHRLEIN
NOTARY PUBLIC
MINNESOTA
My Commission Expires Jan. 31, 2020

EXHIBIT
I 19

EAPC
WIND ENERGY

# Final Report
# Crowned Ridge Wind Farm
# Sound Study
# Codington and Grant Counties, SD

**Submitted To:**
SWCA Environmental Consultants
116 North 4th Street, Suite 200
Bismarck, North Dakota 58501
Tel: 701.258.6622
E-mail: SBaer@swca.com

**Submitted By:**
Jay Haley, P.E., Partner
EAPC Wind Energy
3100 DeMers Ave.
Grand Forks, ND, 58201
Tel: 701-775-3000
E-mail: jhaley@eapc.net

January 22,

2019

**Author:** Jay Haley
Jay Haley, P.E., Partner

EXHIBIT
I20

EAPC
WIND ENERGY

# Final Report
# Crowned Ridge Wind Farm
# Shadow Flicker Study
# Codington and Grant Counties, SD


**Submitted To:**
SWCA Environmental Consultants
116 North 4th Street, Suite 200
Bismarck, North Dakota 58501
Tel: 701.258.6622
E-mail: SBaer@swca.com

**Submitted By:**
Jay Haley, P.E., Partner
EAPC Wind Energy
3100 DeMers Ave.
Grand Forks, ND, 58201
Tel: 701-775-3000
E-mail: jhaley@eapc.net


January 22,

2019

**Author:** Jay Haley
Jay Haley, P.E., Partner

EXHIBIT
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006935

February 19, 2019

Tyler Wilhelm
Project Manager
NextEra Energy Resources, LLC
700 Universe Boulevard
Juno Beach, FL. 33408
Office: (561) 694-3193
Tyler.Wilhelm@nee.com

Subject: Crowned Ridge additional structures

Dear Mr. Wilhelm,

This letter is intended to provide updated landowner participation status information that was not included in the original report titled: "Final Report, Crowned Ridge Wind Farm Sound Study, Codington and Grant Counties, SD", dated February 6, 2019, submitted by EAPC Wind Energy.

After the report was submitted, I was made aware of updated land parcel and farmstead status databases. There were a number of changes in landowner participation status from the original report. Most were changed from non-participating to participating, with a few that changed from participating to non-participating.

There were no changes in compliance with Codington or Grant County requirements for noise limits.

I have attached updated maps and results tables that reflect the changes in participation status for the noise receptors.

Sincerely,

Jay Haley

Jay Haley, P.E., Partner
For EAPC Wind Energy

Attachments:

Appendix A – Crowned Ridge Energy Project Site Overview Map
Appendix B – Wind Turbine Coordinates
Appendix C – Table of Sound Results
Appendix D – Standard Resolution Sound Maps

EXHIBIT
I22

www.eapc.net
EAPC WIND ENERGY
Energy Assessment | Wind Farm Design | Feasibility Studies | Due Diligence | Measurement Systems
3100 Demers Avenue, Grand Forks ND 58201 | TELE 701.775.3000 | FAX 701.772.3605

February 19, 2019

Tyler Wilhelm
Project Manager
NextEra Energy Resources, LLC
700 Universe Boulevard
Juno Beach, FL. 33408
Office: (561) 694-3193
Tyler.Wilhelm@nee.com

Subject: Crowned Ridge additional structures

Dear Mr. Wilhelm,

This letter is intended to provide updated landowner participation status information that was not included in the original report titled: "Final Report, Crowned Ridge Wind Farm Shadow Flicker Study, Codington and Grant Counties, SD", dated February 6, 2019, submitted by EAPC Wind Energy.

After the report was submitted, I was made aware of updated land parcel and farmstead status databases. There were a number of changes in landowner participation status from the original report. Most were changed from non-participating to participating, with a few that changed from participating to non-participating.

There were no changes in compliance with Codington or Grant County requirements for shadow flicker limits.

I have attached updated maps and results tables that reflect the changes in participation status for the shadow flicker receptors.

Sincerely,

Jay Haley

Jay Haley, P.E., Partner
For EAPC Wind Energy

Attachments:

Appendix A – Crowned Ridge Energy Project Site Overview Map
Appendix B – Wind Turbine Coordinates
Appendix C – Table of Sound Results
Appendix D – Standard Resolution Sound Maps
Appendix C – Table of Shadow Flicker Results
Appendix D – Standard Resolution Shadow Flicker Maps

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February 26, 2019

Tyler Wilhelm
Project Manager
NextEra Energy Resources, LLC
700 Universe Boulevard
Juno Beach, FL. 33408
Office: (561) 694-3193
Tyler.Wilhelm@nee.com

Subject: Crowned Ridge participation status changes

Dear Mr. Wilhelm,

This letter is intended to provide updated landowner participation status information that was not included in the original report titled: "Final Report, Crowned Ridge Wind Farm Sound Study, Codington and Grant Counties, SD", dated February 6, 2019, submitted by EAPC Wind Energy.

After the report was submitted, I was made aware of updated land parcel and farmstead status databases. There were a number of changes in landowner participation status from the original report. Most were changed from non-participating to participating, with a few that changed from participating to non-participating.

The following receptors were changed from non-participating to participating.

| Receptors with Participation Status Change | | | |
|---|---|---|---|
| Receptor | First Name | Last Name | Sound (dBA) |
| CR1-G81-P | Nelson E | Ransom | 40.7 |
| CR1-G125-P | Dalton H & Barbara J | Rude | 42.8 |
| CR1-G126-P | Marilyn R | Stemsrud | 39.4 |
| CR1-G127-P | Henry C & Betty Lou | Erickson | 38.8 |
| CR1-G128-P | Ronald & Mindy | Marko | 42.9 |
| CR1-G129-P | Dennis M & Deloris D | Redeen | 36.3 |
| CR1-G130-P | Dalton H & Barbara J | Rude | 39.3 |
| CR1-G131-P | Richard | Hansen | 42.9 |
| CR1-G132-P | Eric | Hansen | 40.6 |
| CR1-G133-P | Laverna | Moldnenhauer | 38.3 |
| CR1-G135-P | Richard | Hansen | 42.6 |
| CR1-G136-P | Duane | FIsh | 42.2 |
| CR1-G137-P | Richard | Fish | 41.6 |
| CR1-G138-P | Harold | Capp | 41.8 |
| CR1-G139-P | Donald | Haacke | 39.8 |

There were no changes in sound pressure results or compliance with Codington or Grant County requirements for sound pressure limits.

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February 26, 2019

Tyler Wilhelm
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NextEra Energy Resources, LLC
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The following receptors were changed from non-participating to participating.

| Receptors with Participation Status Change | | | |
|---|---|---|---|
| Receptor | First Name | Last Name | Shadow (hr/yr) |
| CR1-G81-P | Nelson E | Ransom | 0:00 |
| CR1-G125-P | Dalton H & Barbara J | Rude | 15:48 |
| CR1-G126-P | Marilyn R | Stemsrud | 3:21 |
| CR1-G127-P | Henry C & Betty Lou | Erickson | 2:23 |
| CR1-G128-P | Ronald & Mindy | Marko | 14:58 |
| CR1-G129-P | Dennis M & Deloris D | Redeen | 2:27 |
| CR1-G130-P | Dalton H & Barbara J | Rude | 0:00 |
| CR1-G131-P | Richard | Hansen | 1:31 |
| CR1-G132-P | Eric | Hansen | 7:38 |
| CR1-G133-P | Laverna | Moldnenhauer | 3:26 |
| CR1-G135-P | Richard | Hansen | 8:10 |
| CR1-G136-P | Duane | FIsh | 10:34 |
| CR1-G137-P | Richard | Fish | 18:36 |
| CR1-G138-P | Harold | Capp | 25:18 |
| CR1-G139-P | Donald | Haacke | 8:05 |

There were no changes in shadow flicker results or compliance with Codington or Grant County requirements for shadow flicker limits.

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Energy Assessment | Wind Farm Design | Feasibility Studies | Due Diligence | Measurement Systems

February 19, 2019

Tyler Wilhelm
Project Manager
NextEra Energy Resources, LLC
700 Universe Boulevard
Juno Beach, FL. 33408
Office: (561) 694-3193
Tyler.Wilhelm@nee.com

Subject: Crowned Ridge additional structures

Dear Mr. Wilhelm,

This letter is intended to provide updated landowner participation status information that was not included in the original report titled: "Final Report, Crowned Ridge Wind Farm Sound Study, Codington and Grant Counties, SD", dated February 6, 2019, submitted by EAPC Wind Energy.

After the report was submitted, I was made aware of updated land parcel and farmstead status databases. There were a number of changes in landowner participation status from the original report. Most were changed from non-participating to participating, with a few that changed from participating to non-participating.

There were no changes in compliance with Codington or Grant County requirements for noise limits.

I have attached updated maps and results tables that reflect the changes in participation status for the noise receptors.

Sincerely,

Jay Haley

Jay Haley, P.E., Partner
For EAPC Wind Energy

Attachments:

Appendix A – Crowned Ridge Energy Project Site Overview Map
Appendix B – Wind Turbine Coordinates
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WIND ENERGY

Energy Assessment | Wind Farm Design | Feasibility Studies | Due Diligence | Measurement Systems

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February 19, 2019

Subject: Crowned Ridge additional structures

Tyler Wilhelm
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NextEra Energy Resources, LLC
700 Universe Boulevard
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There were no changes in compliance with Codington or Grant County requirements for shadow flicker limits.

I have attached updated maps and results tables that reflect the changes in participation status for the shadow flicker receptors.

Sincerely,

Jay Haley

Jay Haley, P.E., Partner
For EAPC Wind Energy

Attachments:

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**BEFORE THE SOUTH DAKOTA PUBLIC UTILITIES COMMISSION**

IN THE MATTER OF THE APPLICATION
BY CROWNED RIDGE WIND, LLC FOR A PERMIT OF A WIND ENERGY FACILITY IN GRANT AND CODINGTON COUNTIES

EL19-003

CERTIFICATE OF SERVICE

Ms. Patricia Van Gerpen
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(605) 773-3201 - voice

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(605) 773-3201 - voice

I hereby certify that true and correct copies of the Intervenors' Exhibit and Witness list on June 5, 2019.

/s/ David L Ganje

Ganje Law Offices

17220 N Boswell Blvd Suite 130L, Sun City, AZ 85373

Web: lexenergy.net

Phone 605 385 0330

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