Report on the second meeting on night noise guidelines

Geneva, Switzerland, 6- 7 December 2004

European Centre for Environment and Health
(Bonn Office)
World Health Organization Regional Office for Europe

ABSTRACT

This meeting was the second of the WHO program, co-financed by the European-Commission, on night time noise guidelines. Preliminary drafts of the scientific background papers have been presented and were discussed, particularly exposure assessment, metrics, health effects and the setting up of the guidelines. The experts recommended, each time it will be possible to use the DALYs, an internationally agreed metric, to assess the severity of health impact and to establish guidelines.

The next meeting is planned for April 2005.

Keywords
NOISE
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Background

The WHO - European Centre for Environment and Health - European Centre for Environment and Health, Bonn Office, is coordinating a project to establish WHO night time noise guidelines (NNGL), co-financed by the European Commission DG SANCO. 18 partners are associated in the technical part of the work.

The first project meeting had been convened by WHO in Bonn on the 7 and 8 June 2004, where the project partners, experts and national government officers met to define the work plan and discuss the organizational issues. They also allocated responsibilities, looked at the timetable, team coordination, the logistical and finance. It was agreed that the next step would be the production of background papers for the different identified themes.

The second meeting had been held in Geneva, on 6 and 7 December 2004. This meeting was partly supported by the **Swiss Agency for the Environment, Forests and Landscape (SAEFL).**

Introduction

Dr Kerstin Leitner, the WHO Assistant Director-General for Sustainable Development and Healthy Environments opened the meeting. 22 experts and WHO staff attended the meeting (see participants list in Annex 1). Mr. Xavier Bonnefoy (WHO) acted as moderator.

Dr Henk Miedema, Dr. Stylianos Kephalopoulos and Professor Joao Levy had sent their apologies for not being able to attend the meeting due to different constraints.

Prof Kahn was remembered and praised by the group.

The technical aspects for deriving guidelines were reviewed in detail. The partners presented the first drafts or their substantiating documents for the different subjects and detailed discussions took place for each one of them.

The discussions concentrated mainly on central issues like exposure assessment and guideline derivation. The experts recommended the use of DALYs, an internationally agreed metric, to assess the severity of health impact and to establish guidelines.

Summary of the meeting

Statement of Dr Leitner

Dr Kerstin Leitner welcomed the participants and emphasized the importance of noise as a major determinant of health, and of the WHO role on protecting human health from environmental factors. WHO has the production of guidelines as a major task and Dr Leitner has invited the group to develop standards and guidelines that can be applied to all WHO

Member States (for all regions). She acknowledged that this is a European group but harmonization work should be planned to make the guidelines applicable for all member states.

Member States are requesting advice form WHO, and other international bodies when developing legislation regarding transport and other activities. This group should provide what is, from a health point a view, the levels permissible and the way to achieve this levels. The guidelines should have according to her, a strong section on noise management and mitigation.

Dr Leitner suggested that the group starts by examining the scientific evidence on thresholds, then establishing the maximum values for each source associating, always when possible, a mitigation technique to reach those values. The guidelines document will be much stronger if it contains recommendations on how to achieve the proposed levels. As examples of success stories of noise reduction she pointed the story of the city of Athens where car horns were banned reducing noise considerably, and she also descried the procedure called “the continuous descent approach” for aircrafts for reducing the noise when landing.

Dr Leitner also recommended a very comprehensive peer review by colleagues from other regions asking them to feedback and input on the document.

Presentations by the project partners

The first partners’ project meeting assigned topics to various teams and asked them to provide a first version of their background paper.

After a small introduction the floor was given to the project partners for the presentation of their technical papers.

The next chapter summarizes the presentations’ main content and the discussions that followed. The full papers will not be annexed to this report, since this was an intermediate project meeting and the papers are not yet finalized.

Professor Peter Lercher - Noise management philosophies

For managing noise problems, two different types of noise management approaches are possible:

- specific acoustical approaches which included approaches based on dose-effect relationships, events (oriented towards avoiding or stopping the noise sources) and psychoacoustic factors.
- integrated approaches which included acoustic ecology, soundscape approaches and multi-sectoral environmental health impact assessment approaches.

Establishing guidelines for noise is more complex than for air and water because for these two pollutants maximum concentrations can be defined according to toxicology models. Noise levels on the contrary, can not be established exclusively according to biological effects on human because perception plays an important role (the response changes according to individual sensitivity, source associated perception, among others).

Pr Lercher's presentation then concentrated on different aspects of noise measurement. There are significant differences between seasons on the same measurement site, and also the annoyance response to the same level of noise depends on the site (depending maybe of geography e.g mountain areas versus flat).

The situation regarding day and night time noise exposure distribution is also changing. The tendency is for the differences between day and night time levels to be less, since daytime exposure had stabilized but night/time exposure had increased. One of the main causes of this shift was an increase of goods transport by railway at night. It was likely that the annoyance attributed to this source has also changed.

On the metrics side, according to the Alpine Valley study, geography and distance to the road correlated very well with sleep disturbance.

Professor Jacques Beaumont – Noise metrics and sleep – a proposal of indicators

Prof Beaumont proposed two indicators for noise exposure assessment (effective perceived noise level (EPNL) and transit exposure level (TEL) and presented two case studies for aircraft and tramway noise.

EPNL was to be used for aircraft noise. This index considered the background level and the peak levels being expressed in Perceived Noise decibel (PNdB). TEL was to be used for railway noise and takes into account the speed and length of the train.

In the case studies presented these two indicators performed better than Lnight (equivalent sound level for the 8 hours of the night period) where there were a high number of noise events. For few events (less than 30 times), Lnight varied more slowly than TEL or EPNL. For a large number of events, all the indicators vary in the same order of magnitude. However both new indexes are complex to compute.

Discussion

These two presentations were then discussed. The participants reacted strongly to the second presentation, especially to the proposal of new metrics. It was pointed that existing indicators correlate very well so there is no need to look for and add new indicators. The possibility of including a "distance to the road" parameter was discussed because it correlates well with sleep disturbance.

The group agreed that the number of events was very important and would have to be included, especially for describing awakenings or arousals, but the participants were unconvinced of the advantages of introducing new indicators.

Professor Alain Muzet - Short-term effects of noise on sleep with specific attention to mechanisms and possible health impact

With his presentation Prof Muzet gave a brief overview of the mechanisms through which noise immediately affects sleep. Noise may cause the following short-term effects on the sleep structure: delay of sleep onset, awakenings, sleep stage changes, electroencephalographic arousals, global modifications in temporal organisation of sleep stages and the total time spent in different sleep stages, and premature final awakening. In

addition to these effects, other short-term effects caused by noise are modifications in the autonomic functions (heart rate, blood pressure, vasoconstriction and respiratory rate) and body movements.

It can be considered that chronic short-term effects can provoke more serious and long-term effects on health when they don't disappear with the repetition of the stimulus over a long time exposure e.g. there is no habituation when of frequent exposure.

Body motility changes with noise stimulus at a relatively low level, while behavioural awakening (the strongest instantaneous interference of noise with sleep) has the highest threshold for occurrence of an instantaneous effect considered. In Passchier-Vermeer et al study increased probability of instantaneous motility was found for events with a maximum sound level (Lmax) of 32 dB(A), while behavioural awakening was found for events with Lmax of 42 dB(A). This study also shown that also sleep latency and average motility during the sleep period increased monotonously as a function of the noise exposure level.

The second part of the presentation focused on possible risk groups to noise. This can be people reporting sensitiveness to noise, shift-workers and night-workers. People sensitive to noise normally complain and protest more against noise.

Several authors have studied individuals reporting noise sensitivity as a factor to evaluate highly sensitive and non sensitive groups and to compare their reactions to noise exposure during daytime and night-time. In the laboratory studies self declared highly sensitive individuals had higher cardiovascular response rates to noise than non sensitive while they were awake, nevertheless there was no difference in sensitivity to noise between the two groups while they were asleep.

The sleep of shift workers is often disturbed by combined influences of ambient factors (noise is one of them) and chronobiological factors (e.g. sleeping at an unusual time of the day), but noise was considered as the first cause of sleep interruptions in a shift worker female group study.

Discussion

The cardiovascular function is a basic reflex function and that is why it does not habituate to noise. Elderly and children are more reactive. During the night it is "observed" more because during the day the information processing through the cortex is different and the individuals can "ignore" the signal. The response also depends on the sleep stage in which the person is.

Professor Sona Nevismalova - Long term noise-induced health risk mediated particularly by sleep

When a person has his/her sleep disturbed by noise the following effects are observed:

- reduction of sleep efficiency,
- increased number of arousals,
- increased stage shifts,
- increased movement time,
- increase of REM sleep,
- decrease of slow wave sleep (NREM 3 + 4),
- and a decrease of total sleep time

These effects, when chronic, can have persistent and permanent effects on mental and physical health of exposed people.

We can observe the first changes on sleep at noise levels of 45 dB(A) Leq. When this level is observed a decrease of REM sleep stages and a decrease of slow wave sleep (NREM 3+4) occur. These changes are more pronounced at 60 dB(A), where a big decreases of REM sleep is observed and we have superficial synchronous sleep (NREM 2) dominating. Several studies demonstrated that intermittent noise has a more disturbing effect on sleep than continuous.

Several environmental stressors including noise can cause insomnia. Insomnia is commonly defined as a difficulty in initiating and/or maintaining sleep. According to a research group of the U.S. National Center for Sleep Disorders Research (1999), “insomnia is an experience of inadequate or poor quality sleep characterized by one or more of the following: difficulty falling asleep, difficulty maintaining sleep, waking up to early in the morning, non-refreshing sleep“. Insomnia also involves daytime consequences, such as “tiredness, lack of energy, difficulty concentrating, and irritability“.

It is estimated that around 10% of the population have chronic insomnia, when considering insomnia of any duration or severity this number increases to between 30% and 50% of the population. Developing insomnia increases with aging and women are particularly vulnerable to insomnia in the course of their perimenopausal time.

Risk groups for having their sleep disturbed by noise were identified by Professor Nevismalova, similarly to the previous speakers:

1. sensitive subjects (anxious and with neurotic tendencies);
2. children (because the growth hormone is segregated during SWS sleep and the REM sleep is crucial for memory);
3. women during pregnancy and perimenopausal period
4. shift workers
5. elderly people (their sleep is more superficial)
6. patients at intensive care units,
7. low-birth weight infant units,
8. and residents and disabled persons in nursing homes.

Besides healthy population, standards should be recommended and strictly adhered to in hospitals, particularly at intensive care units.

Dr Leja Dolenc Grošelj - Physical effects resulting from night time noise exposure

Dr Groselj’s presentation covered the “next day effects” after having a disturbed sleep by night time noise exposure. There is solid evidence that noise interferes with sleep, awakenings being the most common consequence. Noise events interrupt the sleeping process for a period of time going from a few seconds to several minutes. The repetition of these sleep modifications throughout the night may lead to chronic sleep loss with consequences such as chronic fatigue, sleepiness during daytime, and a global poor life quality.

Extensive studies dealing with sleep disturbances caused by noise exposure have been published during the last ten years. Most of them are dealing with sleep fragmentation and its consequences, insomnia being the most serious consequence. However, fatigue, drowsiness

and excessive daytime sleepiness were significantly less studied. Most of the studies dealing with daytime consequences were subjective. Objective studies with laboratory measurements are lacking.

Discussion

It is extremely difficult to measure fatigue and sleepiness. The only way is by asking people. There is no harmonized way of measuring it. Sleep recordings can be performed but they are rather difficult and expensive. One possible solution would be to adapt the results for insomnia; this is probably the only way to have health data on this subject.

Professor Stansfeld; Dr Michal Skalski - Night noise and mental health

Professor Stansfeld described the associations between noise (transport, neighbours and occupational) and mental health. Limited data exists for night noise, also due to the fact that occupational noise findings can not be used. It is generally accepted that noise exposure at night is more disturbing than daytime noise because it interferes with rest and sleep. Because there is little direct research on night time noise and mental health the evidence for environmental noise and mental health in general was analysed first.

Results of several studies were presented. In these studies the association between noise and mental health has been examined using a variety of outcomes including individual symptoms (at the simplest level), psychiatric hospital admission rates, use of health services, psychotropic medication, and community surveys. 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 there are more serious effects.

Further research is needed on mental health effects originated from exposure to very high noise levels. Existing studies may be confounded either by prior selection of subjects out of noisy areas or by confounding noise exposure, socio-economic deprivation, and psychiatric disorder. It is also possible that people underestimate or minimise the effects of noise on health through “optimism bias” this is a particularly protective factor for mental health. If a person copes well with the noise it is less likely that it has a harmful effect.

Depression is heavily associated with insomnia, but not much is known about the mechanisms linking insomnia to depression. Anxiety and insomnia have similar causes and it is very difficult to distinguish which triggers which.

Population, as well as clinic-based studies, have demonstrated a high rate of psychiatric morbidity 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.

Discussion

Noise as a stressor affects health in a different way from the other stressors. Noise is a classical stressor involved in the processing of information but during daytime, the brain can “ignore” it and a positive reaction towards it will reduce its effects (e.g. when associated with fear, negative attitude regarding the source the effects are much higher).

People with mental health problems, likewise paranoia, can be extremely affected by noise (all noises are seen as threats). More research is needed to needed to identify night time exposure and its relationship to mental health.

Dr Christian Maschke – Stress mechanisms

Noise triggers a stress reaction, the crucial question is whether noise can actually be regarded as a stressor that induces health damages, mainly in the pathogenesis of cardio-vascular diseases.

Stress is a non-specific reaction of a living organism, which can be triggered by any exogenic or endogenous (including cognitive and emotional) induced stimulation involved in the information processing of the central nervous system. It can cause temporary or permanent functional or structural changes in all body systems. Eustress (positive stress) promotes performance and health; distress (negative stress) is a variety of stress with a pathological appearance.

There is biological plausibility of noise being a psycho social stressor activating the sympathetic and endocrine systems and there is sufficient evidence that noise levels higher than 50 dB (A) disrupt strongly the hormone secretion cycles.

The non-specific reaction by stress is strongly modified by:

- the individual functional condition (activation is not only dependent on the volume of the acoustic stimulus, but is also determined for example by vegetative excitation levels and subjective perceptions of influence)
- habituation – dishabituation (habituation to noise) is only to be expected in cases of acute stimulation or low intensity)
- conditioning of the non-specific reaction (in terms of noise, negative emotions essentially triggered by conditioning include anxiety, fear, helplessness and defencelessness)

Hormones are secreted according to a rhythm. The time a person takes to recover from a stressed situation depends very much upon individual characteristics and of the emotions they experience.

Persons that express hostility have a higher risk of cardio vascular diseases, this is also true to noise. The more a person is hostile to it, the higher is the risk of cardiovascular dysregulation. No-acoustical factors play a big role in this process.

The chronobiological stress caused by night noise occurs during the most important period for a human beings recovery! It is extremely important to preserve this period to maintain the balance necessary for good health.

Discussion

Hormones during sleep are secreted on a pulsatic way, following a similar pattern, e.g. the growth hormone secretion can be affected by a noise stimuli, however there is a gap a gap on knowledge on what the effects would be of disturbing these patterns.

Dr Wolfgang Babisch - Health effects related to stress mechanisms - Cardiovascular effects

Dr Babish has carried a very comprehensive literature review. He has selected the studies according to the WHO document “Evaluation and use of epidemiological evidence for risk assessment”. Using all six criteria of the document for considering epidemiological studies, 5 studies emerged that refer to the association between road traffic noise and ischaemic heart disease. The presentation focused on these studies even though the other studies were also mentioned.

All the five studies were analysed and published with respect to clustered data (high vs. low exposed), which raises some concern regarding its application for the derivation of guidelines. One of these studies was considered in the earlier meta-analysis (the only one) for aircraft noise and hypertension. When dose-response studies on self reported prevalence of hypertension are included, two more peer-reviewed studies appear on the list. These studies were carried out in Berlin (Germany) with respect to hypertension and Stockholm (Sweden) with respect to aircraft noise.

Nearly no information is available from epidemiological studies on the cardiovascular effects of long-term noise exposure, particularly, during the night-time or with respect to the exposure of the bedroom. Only one study suggested slightly higher effect estimates with respect to the exposure of the bedroom (during the night) compared with the exposure of the living room (during the day). However, this study has some methodological limitations that were also addressed in a recent report of the Dutch Health Council. A few studies regarding subjective responses to community noise suggest a closer relationship of cardiovascular diseases with sleep-related annoyance and disturbance reaction rather than with non-sleep related annoyance/disturbance. Closing the bedroom window or, vice versa, sleeping with the bedroom window open, was associated with a, respectively, lower or higher risk. The same was found with respect to swapping bedroom and living room because of noise. These findings may indicate that night-time noise may be more a determinant of noise-induced cardiovascular effects than the daytime exposure. However, during daytime time-activity patterns and expectations of the individuals are much more inhomogeneous than during the night, which dilutes possible effects.

Given the prevailing situation, there does not seem to be any other way of reasoning than inferring night noise recommendations or guidelines from the results of epidemiological studies that refer to the noise exposure during the daytime period (Lday) or the whole day (Ldn, L24h). Lden appears to be a useful noise indicator for formal decision-making and regulatory purposes, but not for noise effects' research. Such global noise indicators refer normally to the most exposed facade, which incorporates a certain degree of exposure misclassification regarding cause-effect relationships.

However, in urban settings, night-time average noise levels from road traffic tend to be approximately 7-10 dB(A) lower than daytime average noise levels. In such cases, Lden is approximately 2 to 3 dB(A) higher than Lday. Therefore, in epidemiological studies in which the relative effects of road traffic noise is 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 since existing noise regulations usually consider a 10 dB(A) difference between the day and the night, which is also incorporated in the construct of Lden. With respect to railway noise and aircraft noise no such stable relationship can be assumed. The day (night difference depends very much on the cargo traffic during the night and existing night-flight restrictions regarding airports. Assuming these

circumstances epidemiological studies can be considered for the development of night noise guidelines that were not focussing explicitly on the exposure during the night. This approximation can, particularly, be made with respect to road traffic noise. With regard to aircraft noise and the night-flight problems in the vicinity of busy airports, at present no other alternative exists than the approximate transfer of the quantitative risk observations derived from road traffic noise studies to aircraft noise. However, since aircraft noise acts on all sides of a building, i.e. different to road traffic noise, the suspicion exists that the effects induced by aircraft noise could be greater than those induced by road traffic. This may be due to of the lack of evasive possibilities within the home, and the greater annoyance reactions to aircraft noise, which are usually expressed in social surveys.

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, coping and habituation may be reasons for an empirical threshold of effect. Decisions with respect to guidelines values should be based on a quantitative risk assessment – not ignoring the individual risks of exposed subjects, if considered as relevant.

Discussion

The expert has considered that sufficient evidence exists for noise exposure and ischemic heart disease even if there aren't a large number of studies. A significant increase is observed for 65 dB(A) during day time and 55 dB(A) for night time.

A new meta-analysis using all the mentioned studies can be performed, but the author would have to be able to consult the original studies (not only the summary and the published results).

Dr Svenaza Yovanovic – Childhood accidents

Apparently there is only one study on children (Udine hospital, Italy) and the recent LARES survey dealing with accidents and noise. Some data exist for falls, poison, ingestion of toys or other strange objects, heavy injuries and road traffic accidents but no linkage has been done with noisy conditions at the school or home.

One very interesting fact is, as shown by a Swedish study, that twenty five percent of school injuries (in children between 7 to 19 years old) are caused by other pupils. Some of this violence and aggressiveness can be related to noisy conditions.

A German study carried in Cologne, with 5000 children, has shown associations between bad sleep conditions and aggressiveness. Leger and al. have published a paper where it is described that 40% of car accidents and 30% of work accidents are sleep related, for domestic accidents the main risk factor is having a sleep disorder. Sleepiness is related to accidents but again, there is a lack of studies with covering the relation with noise.

Discussion

Knowledge exists for sleep reduction and risk of accidents but insomnia does not always lead to sleep reduction. Attention has to be paid to speculation around this theme, only clear and solid results should be used.

The results of occupational noise can probably be used, Prof Lercher has carried a meta-analysis for the ICBEN congress in 1998 and has found some data for noise at workplace and accidents.

An accidents risk assessment can also probably be made using insomnia as a model. When insomnia is caused by noise what is the risk of accidents? Can an extrapolation be made from the existing literature that noise at night causes x work accidents, y traffic accidents, z domestic accidents?

Dr Staffan Hygge - Night noise and cognitive impairment

Prof Hygge has performed a review on the effects of night noise exposure on cognitive performance. Searching PsychINFO for (noise AND night AND (memory OR learning OR attention)) resulted in nine hits, all related to sleep or irregular sleep patterns or night shift work. In contrast to this lack of reported research, searching Google with the same keywords and operators yields 2.7 million hits. Subtracting all texts with a reference to sleep left a remainder of 1.8 million hits. This discrepancy in numbers between texts reporting research and other texts containing the same keywords may reflect a situation of high interest but little of hard facts.

There are links between night time exposure and reduced sleep quality and between reduced sleep quality and cognitive performance; however the links between night noise exposure and cognitive performance are missing. This is the ones we will have to concentrate on.

Several difficulties were encountered relating to:

- day and night time exposure
- children and adults differences
- restoration
- communication and noise

During the night we are not “learning” but there are important functions occurring in the brain like memory storing. It can also be the case that noise doesn’t have an impact on cognitive system, but it only lowers motivation and ambition that possibly lead to problems in school.

Discussion

Can the processing memory mechanism be described? And what part is affected by night time noise? It is known that Cortisol plays a crucial role for memory process, for instance if there is an increase of cortisol there is a lack of next day memory but we don’t know if the memory is affected through other mechanism. It is also known that it is not cortisol that affects memory, a disruption of its normal secretion rhythm shows a disturbed sleep. Cortisol is a stress hormone, people highly stressed during the day need a better sleep, and everything is linked.

Knowledge on noise and hormones is rather limited! Specialized literature exists for the “normality” and the role of the hormones on a good health. The guidelines should consider having a chapter on this and infer on the possible effects of noise. Like in other health determinants the group should use the precautionary principle and be based on the existing knowledge.

Professor Halmut Ising - Animal Studies

Noise has often been used as a stressor in animal studies. Most of the modern animal studies testing the pharmacological effects of drugs are carried out with and without various stressors. The animal model for auditory effects in humans has been established in great detail, a 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 usually met in daily life.

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

Beside cardiovascular stress effects, chronically increased cortisol may induce neuronal degeneration and thus accelerate the ageing also of the brain not only in rats but in humans as well.

The importance of calcium magnesium shifts was confirmed by post mortem studies of hearts from victims of ischaemic heart diseases (IHD). 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.

Long-term experiments with magnesium deficient and noise-stressed rats showed that connective tissue and calcium in the myocardium increased with age while Mg decreased. Hence, stress caused by noise or cold is enhanced by sub-optimal Mg intake and accelerates the ageing of the heart and decreases the life span.

Rhesus monkeys exposed to traffic noise for 10 h/day during 9 months (Lmax=97 dB, Leq=85 dB) developed significant blood pressure increases persisting 3 weeks after termination of exposure. A replication of this experiment with a different species of primates failed to show an increase of blood pressure.

Some important factors influencing health effects of chronic noise exposure:

- Unpredictability of noise events
- Genetic factors (inbreeding)
- Combination with other stressors

Animal studies shown that chronic noise-induced stress accelerates the ageing of the myocardium and increases the risk of myocardial infarction. The involved pathomechanisms include: increases of catecholamines and/or cortisol and an interaction between endocrine reactions and intracellular Ca/Mg shifts accelerating the ageing of heart and circulation.

Discussion

Magnesium deficiency is an effect of noise exposure but there are contradictory results. A person needs time of no-stress for reabsorb magnesium. Cortisol is a better indicator than noadrenaline. This patterns need to be well described.

Professor Oliviero Bruni - How to take into account the specific needs of children. Children's sleep

In the last few years, a growing body of literature demonstrated the strict relationships between sleep disturbances and daytime dysfunctions. Results from recent quantitative research on noise as an environmental stressor consistently demonstrate that children are more vulnerable than adults to the adverse effects of noise exposure especially when considering the effects on cognitive performance, motivation and annoyance.

Data shows that children with sleep-related obstructive breathing disorders (SROBD) are less reflective, more impulsive and show poorer sustained and selective attention, memory impaired and showed reduced academic performance and learning. Early treatment showed that attention deficits in OSAS (Obstructive Sleep Apnea Syndrom) children are reversible. Actigraphic study in school children showed that lower sleep efficiency and longer sleep latency were associated with a higher percentage of incorrect responses in working memory tasks. Almost thirteen percent of children that have frequent and loud snoring during early childhood report low academic (versus five percent with high academic performance). Healthy children with fragmented sleep showed lower performance on neurobehavioral functioning (NBF) and had higher rates of behaviour problems.

Children and adolescents with disturbed sleep report more depression, anxiety, irritability, fearfulness, anger, emotional instability, inattention and conduct problems, and drug/alcohol use in adolescence. At 3, 4 years of age persistence or recurrence of infant sleep problems is common and associated with higher aggressive behaviour and somatic problems and maternal depression scores.

A study exists for the increased risk of accidents. In Italy for 292 injured children who presented at the Children's Emergency Center of Udine, there was a direct association between injury risk and sleeping less than 10 hours. Among 3 to 5 years old boys there was reported an 86% increase risk of injury.

Inadequate sleep duration and lack of daytime naps (in school) are transient exposures that may increase the risk of injury among children.

Although we should take into account that it is at present impossible to indicate whether children are possibly more sensitive than adults to other direct biological effects of night-time noise, we can hypothesize the effects of night-time noise during sleep in children based on inferences of adult studies.

It is known that adults' physiological responses appear at an Leq in the bedroom of approximately 40 dB(A) and behavioural awakening occurs when the bedroom *Lmax* exceeds 55 dB(A). Since child's autonomous nervous system is more readily activated by noise (acoustic stimuli of much lesser intensity 10 to 15 dB) when sleeping than an adult's, it can be assumed that children are more sensitive also to detrimental effects of noise exposure.

In the following table the effects of sleep disruption specific to children, based on literature evidence are described.

Effects of sleep disruption in children induced by noise

Short term	Behavioral	Daytime fatigue; decreased performance and concentration, memory difficulties; difficult behavior; increased motility
	Medical	increased heart rate; use of sleeping pills and sedatives
	Mortality	Increased risk (Sudden Infant Death syndrome) ?
Long term	Behavioral	Difficulty in modulating impulses and emotions; poor performance at school, fatigue, memory difficulties, concentration problems; impaired well-being and motivation: increased risk of accidents; increased motility
	Psychiatric	Depression, anxiety conditions; aggressive and delinquent behaviour; attention-deficit/hyperactivity disorder; alcohol, smoking, caffeine and other substance abuse (?)
	Medical	Increases in sleep disorders (parasomnia); changes in blood pressure; changes in carbohydrate metabolism; changes in immune system (?);use of sleeping pills and sedatives
	Mortality	Increased risk (Sudden Infant Death syndrome) (?)

During what can be considered a “normal” sleep in average a child should not have more than 7 awakenings per hour.

In order to quantify or to specify limits for sleep disturbances induced by noise in children the following table can be established:

	Preschool	Sleeping in School
Night noise limit	*Leq* <30 dB(A)	*Leq* <30 dB(A)
Arousal n°/h	< 7	< 9
Cyclic AP rate	< 30%	< 35%
N° awakenings	> 2 lasting > 15’	> 2 lasting > 15’

Children should be considered as a risk group, specially the ones that have a low birth weight, are small for gestational age babies, have had preterm birth, are already having learning disorders behavioural disturbances (i.e. hyperactivity) and already have sleep disorders.

Discussion

This presentation raised a large discussion about the proposed guideline values. There was a problem with the metric used (SEL and Leq) that is already corrected in this report. The proposal of the CAP rate and number of arousals was questioned but Professor Bruni shown the results of the studies where he has based his results.

Professor Bruni was asked on the number of arousals and Cyclic Alternating Pattern (CAP) and its relationships with noise. How can this be measured?
During NREM, sleep maintains an oscillating pattern that reflects different levels of arousal that has been coded as CAP. CAP is a periodic EEG activity of NREM sleep characterized by repeated spontaneous sequences of transient events (phase A) which clearly breaks away from the background rhythm of the ongoing sleep stage, with an abrupt frequency/amplitude variation, recurring at intervals up to 1 min long. The return to background activity identifies the interval that separates the repetitive elements (phase B).

Simplifying the CAT rate can be an indicator of sleep quality. The potential indicators of sleep disruption in children are mainly represented by arousals and cyclic alternating pattern (CAP).

Literature shows that reactions smaller than a sleep stage change correlate better to the noise intensity than awakening reactions. Arousal analysis, CAP analysis and identification of new parameters of sleep fragmentation (sleep pressure score) in children can give new insights on the relationships between sleep disruption and cognitive consequences.

Lnight can not be the only descriptor of a good sleep, the number of arousals, the CAP rates and awakenings will also have to be defined. The guidelines will have to consider descriptors of good sleep.

The remaining question that was rose is how to calculate these parameters, what should be the relevant metric to put into legislation!

Dr Mueller – Wenk - Determining the severity of noise-related human health effects within an established health metric system

Amongst noise-related health effects, small impairments affecting large fractions of a population may be more important than a small number of noise-related severe effects, even deaths. To obtain a comprehensive picture of noise-related health damages, it is advisable to link dose-effect-relations to the severity weights of the respective health impairments.

The DALY concept, as widely used by WHO, is an advantageous health metric system for assessing noise-related impairments. Until now, health endpoints of available dose-effect relations are not enough precise for an attribution of severity by medical experts.

Noise-related sleep disturbance is clearly a disability (and not merely an annoyance), and its disability weight was rated by medical experts roughly equal to 'chronic Hepatitis B infection without active viral replication'. A second study with Obstructive Sleep Apnoea Syndrome (OSAS) confirmed that this rating is conservative. Sleep disturbance is the dominant component of the road-noise-related part of the Swiss burden of disease.

In order to strengthen the scientific support for more effective noise abatement, Dr Wenk recommends the group to concentrate on the following activities:
- make a provisional ranking of the importance of the health effects to be considered in the perspective of a person's burden of disease.
- agree on properly defining the health endpoints of dose-effect-relations, so that it is possible to attribute a severity weight to these health endpoints, preferentially within the rules of the DALY system;
- agree on the question of positioning disabilities as hypertension, increased blood lipids, interference with speech communication, annoyance.
- decide on the most important and necessary dose-effect relations, and proceeds to a collection of available preliminary data for these.
- agreeing on a list of missing disability weights covering the noise-related health effects.

Discussion

The group agreed with using the DALY methodology because it is a common international health metrics and will allow a common language for the major health determinants. In addition it is of interest for the decision makers when having to make decisions regarding different pollutants.

Dr Martin Van den Berg – deriving guideline values for night noise

Dr Van den Berg has based his analysis on three documents, “Evaluation and use of epidemiological evidence risk assessment (WHO publication)”, the “Air quality guidelines for Europe (WHO, 2nd edition)” and the recent report from the Health council of the Netherlands “Influence of Night time noise on sleep and health”.

A general approach for deriving guidelines consists in undertaking several steps:
1. Assessment of the impact on the population;
2. Evaluating the impact;
3. Assessing options to avoid or reduce impact considered undesirable;
4. Cost-benefit analysis of the options or of mix of options;

5. Assessment of the preferred option;
6. Implementation.

As steps on Health Impact assessment (following the WHO document evaluation and use of epidemiological evident), the data has to be collected and validated, the metrics of exposure have to be specified and the health outcomes defined. Then the methods for estimating the exposure response relationships and the baseline frequency of health outcomes specified for assessing the attributable cases to noise.

The criteria for evaluating studies could be by separating the biological and health effects, then evaluating the significance of health effect, establishing the exposure-effect process based on the strength of the evidence for each relationship .

The health council of Netherlands reports that noise affects the quality of sleep, general well – being, social contacts and concentration and medical conditions reducing consequently life expectancy.

Sleep quality	Reduced perceived sleep quality Difficulty getting to sleep, difficulty staying asleep Sleep fragmentation. Reduced sleep time Increased average motility when sleeping	Sufficient evidence Sufficient evidence Sufficient evidence Sufficient evidence
Well being	Sleep disturbance Health problems Use of sleeping drugs and sedatives Increased daytime irritability Impaired social contacts Impaired cognitive performance	Sufficient evidence Sufficient evidence Sufficient evidence Limited evidence, plausible Limited evidence, plausible Limited evidence, plausible
Medical	Insomnia Hypertension Depression (in women)	Sufficient evidence Limited, indirect evidence, plausible Limited, indirect evidence, plausible
Premature mortality	Cardiovascular disease Occupational accidents	Limited, indirect evidence, plausible Limited, indirect evidence, plausible

Effects on health and well being of prolonged exposure to noise during the sleep period (the health council of the Netherlands, 2004)

Deriving guidelines (taking the example of the air quality) is always a complex process. There is always lacks on knowledge and it is very difficult to have all the evidence with full confidence. Quoting the air quality guidelines: “Ideally, guideline values should represent concentrations (…) that would not pose any hazard to human population” - “Although a certain risk can be tolerated” - “The use of a standard approach is impossible”.

There are different approaches for establishing guidelines for night time noise, a first possibility is to write a document with the state of the art without providing guideline values, another possibility into provide DALY-weighting for all end points and the last avenue could be to give the same protection as other existing and solid guideline values (e.g air quality – Lnight of 40 dB same protection as NO2= 40 ug/m3 (WHO air quality guidelines)).

For controlling noise during the night a restriction of night time activities can be envisaged, or the use of only quiet equipment during night time. Another type of measures is the banning of

noisy activities from sensitive areas (e.g. residential areas) or the other was around taking sensitive activities from noisy places or insulating buildings. All these measures are very expensive and not easily put in practise.

It could be concluded that firstly all the information and evidence have to be collected, that, based on solid facts the group has to decide if and what guideline values to use. The evidence should be systematically assessed for validity and strength.

Discussion

Guidelines values will be established, if the group produce only recommendations nothing will change on the noise field. The guidelines should have a protective role and will be based on the best available evidence. Risk assessment methods and DALY approach could be used when there are minor gaps in the knowledge.

Mr Colin Grimwood - Neighbourhood Noise - guidelines

Mr Grimwood's presentation concentrated on how to consider neighbourhood noise in the night noise guidelines. Should guideline values be defined or just recommendations and good practice advice be provided?

Deriving guideline values for neighbourhood noise is a very difficult, not to say impossible, task. First a clear definition for neighbourhood noise has to be agreed upon. The existing definitions are:

- Transportation noise - noise from the normal operation of a mechanised mode of transport, primarily road vehicles, rail vehicles and aircraft.
- Neighbour Noise - noise from people, pets and the use of domestic appliances in and around residential premises.
- Neighbourhood Noise - all other noise sources produced in the neighbourhood!

Mr Grimwood had not undertaken a literature review but he can confidently state that there are less studies on night-time neighbourhood noise than transport noise, and only those made in last few years are likely to be suitable for intercomparisons.

The second major question raised was whether a night-time neighbourhood noise guideline would be an appropriate approach for all neighbourhood noise sources. How would a guideline value be enforced? Additionally some countries (e.g. Switzerland) have different institutions dealing with the different noise sources. Environmental, occupational and neighbourhood noise are under the responsibility of different governmental agencies and levels (neighbourhood noise is usually dealt at local level).

The approach for regulating neighbourhood noise has to be a holistic approach. Firstly a noise impact assessment has to be made, considering the absolute level of noise and any possible noise changes. In addition the non acoustic factors need to be taken into account (time-of-day, season of year, type of area, attitudes to source, neuroticism, negative affectivity, individual sensitivity to related pollutants, expectation, history of noise exposure, employment or other connection with the noise source, education, home ownership, type of dwelling, length of residence, etc). The context is very important and factors like behaviour and other social factors need to be considered as well as other factors such as acoustical insulation.

The way different countries deal with neighbourhood noise is also different. For example, in England the generalised findings on dose/response, sleep disturbance, effects of change, role of non acoustic factors applicable to the different types of neighbourhood noise are not used in primary legislation for any neighbourhood noise source. Instead the law allows environmental health practitioners and the courts to take such factors into account when assessing the likelihood of noise nuisance. Nevertheless, there are a few examples of guideline values in use in England for night time neighbourhood noise (mixed sources, outdoor concerts, industrial noise, night time neighbourhood noise).

An issue that needs to be explored through further research is if there are unique factors (acoustic and non-acoustic) that are applicable to the different categories of neighbourhood noise.

Examples of existing guideline values for some sources were presented for England.

Industrial Noise

- Assessing likelihood of complaints from industrial noise
- Uses a 'relative guideline'
- Noise is measured or calculated (LAeq, T), corrections applied (impulsiveness, tonality, irregularity, time of day etc.) and compared with background noise level (LA90,T)
- Applies to day and night (but BS4142 method further weights night noise by use of shorter reference T period)
- Note 'night' is decided locally but 'is intended to cover the times when the general adult population are preparing for sleep or are actually sleeping'.

Noise Act 1996 "Neighbourhood Noise"

- Specific for night (defined as 2300 - 0700)
- Uses a 'relative guideline'
- Where the underlying level of noise does not exceed 25dB, the permitted level shall be 35dB
- Where the underlying level of noise exceeds 25dB, the permitted level shall be 10dB in excess of the underlying level
- noise source measured as LAeq, 5min
- underlying level - level not exceeded for 0.6s in 5mins (e.g. LA99.8, 5min or LA99, 1min)

One very interesting fact is, based on two national noise surveys undertaken in 1990 and 2000 and involving over 1,000 measurements each, that environmental noise during the night is increasing whilst noise during the daytime is very slightly decreasing. If this trend continues then it would result in the same levels for night and day (currently there is a marked decrease at 00:00 but the noise just goes up again around 04:00 until reaching a peak at 08:00).

Discussion

The noise of neighbours is increasing, it is one main cause of complaints and dispute among communities, establishing guidelines will not provide a solution to all problems. There are a lot of non acoustical factors; the situation has to be seen case by case. Listing the noisy activities that should be banned at night (vacuum cleaning, having the television or the stereo at a high sound,…) and giving good practice recommendations is one possible approach.

Conclusions and recommendations :

1. In many countries there are indications that noise during the night period is increasing practically to the same level as during day (examples of Austria and England). The night period when the noise levels are low is becoming very short (3 to 4 hours).

2. When there are significant risks of damage to the public health, WHO should be prepared to provide guidance in order to allow authorities to take action to diminish those risks, even when scientific knowledge is not conclusive.

3. The existing WHO guidelines are based on experts' best judgements. The consensus and advice of this group will be one of the crucial elements of the final document.

4. Annoyance should be seen as a short term response to noise exposure. Long term annoyance leads to ill health (higher susceptibility to disease).

5. Some short-term health effects when occurring on a long period of time might become chronic. In other words, there is no habituation, even after a long exposure time.

6. It seems plausible that night time noise has an effect on mental health. The links need to be further evaluated.

7. Noise sensitivity could be related to anxiety; anxious persons were more sensitive and had less capacity to adapt to a situation. A person already suffering from mental health problems (as anxiety, depression or paranoia) would be more vulnerable to noise than a healthy one.

8. Night time intermittent noise had worse health effects on sleep than continuous noise covering the same energy over the exposure period.

9. Guidelines should be recommended for hospitals, particularly at intensive care units.

10. Fatigue, drowsiness and excessive daytime sleepiness need to be studied more, as does their association with accidents (identification of a causal link).

11. More studies looking into associations, and if possible links, between children's accidents, aggressiveness, and hostility and noise should be carried out.

12. WHO should organize a new meeting of experts on chronic insomnia covering in detail its causes and health effects.

13. Cortisol excretion during the night and its effects should be better evaluated. A review covering the knowledge and the existing evidence of cortisol excretion should be included in the guidelines.

14. The internationally agreed WHO metric DALY, should be used to assess the severity of health impact and to support guidelines whenever possible.

15. When studies concentrating on the night period are missing, extrapolations from exposure during daytime could be made.

16. When there are gaps in knowledge, guideline values could be established in order to give the same protection as existing guideline values in other environmental fields (water, air,…). The evidence should be systematically assessed for validity and strength.

17. Population more at risk to night noise are:
    Children:
        Low birthweight
        Small for gestational age babies
        Preterm birth
        Dyslexia and hyperactivity

    Adults:
        sensitive subjects (anxious and with neurotic tendencies);
        individuals with pre-conditioned lighter sleep (eg women during pregnancy perimenopausal period, elderly people and shift workers);
        patients in intensive care units;
        residents and disabled persons in nursing homes.

Main gaps in Knowledge at this stage

1. The role of stress hormones on the autonomic and cognitive functions needed to be better evaluated, especially excretion of Cortisol during the night.

2. Causes and health effects of insomnia should be evaluated and described in detail.

Guideline development – a possible way forward

The guideline development will be fundamented on establish values that prevent the occurrence of harmful health effects. At this stage the plausible health effects, either direct or indirect, of exposure to noise during the night can be listed. For some effects solid evidence exists and noise thresholds values can be defined, for others a protective threshold can be established. For the effects for which solid evidence is missing an approximate approach based on day time findings, supported by animal studies, and based on the precautionary principle, if needed, will be used.

For children the guidelines values will the ones ensuring a healthy sleep. For the time being (based on Pr Bruni's paper) this can be the lower level of noise for which studies demonstrate a clear and significant disturbance of the sleep of the children. A more in depth discussion needs to be carried out, especially on the health impacts on children of a disturbed sleep on a long term basis.

For adults the effects to be considered are sleep disturbance and its associated effects, cardiovascular effects, the possible mental health effects, especially among the population already suffering from a poor mental health.

The metric to be adopted should consider the average background noise level that does not provoke adverse effects and will have to allow an evaluation of the number of arousals and awakenings.

Follow up work

In the plenary session on the last day of the meeting, the group established and agreed to hold the third meeting on the 26 and 27 April 2005 in Portugal. The table of contents (annex 1) and the authors of each chapter have been updated. The partners will review and finalize their papers according to the comments made during the present meeting and the final version will be discussed on the next meeting.

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Pr Beaumont; Dr Kephalopoulos; Pr Lercher; Pr Levy; Dr Licitra

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Short description of the various situations across countries
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Dr. Leja Dolenc Groselj

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Dr Maschke

III- 3. Short term Instantaneous effects (sleep and non sleep related)

Dr Miedema, Prof Muzet

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Pr Nevismalova

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Dr Stansfeld, Dr Skalski

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Dr Babisch

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Pr Hygge, Pr Stansfeld

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Dr Maschke, Dr Jovanovic

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