Experts consultation on methods of quantifying burden of disease related to environmental noise

**State Health Agency of Baden-Württemberg
Stuttgart, Germany, 23–24 June 2005**

ABSTRACT

On the 23rd and 24th June 2005, in the District Government of Stuttgart, a group of international experts met to define and agree on the assessment of burden of disease (BoD) from environmental noise. Discussions took place on methodology, country approaches, exposure and health outcomes to consider. The methodology previously proposed by WHO will be used, the exposure data will depend on the competency of Member States, and the health outcomes to consider will be hearing loss, tinnitus, cardiovascular outcomes, sleep disturbance, injuries, and cognitive and developmental impairment. Annoyance will also be covered as a separate topic. A second meeting is planned for December for discussing the first draft of the document estimating BoD of environmental noise.

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Introduction

Although it is well known that noise is an important environmental factor that affects health, the magnitude of the health problem due to population's exposure to noise is not well quantified. For example, we have a limited knowledge of what 20% of the population annoyed by noise mean in terms of public health, what the respective consequences of the noise exposure from different sources (occupational, leisure, home, etc…) are, what the magnitude of health change in the noise landscape (opening or closing of new air corridors, increase or reduction of traffic, new regulations in force…) is, and so on.

Harmonized methods should be used to assess and calculate the environmental noise impact on health. WHO has already developed practical guidance for the estimation of disease burden at national or local levels for selected environmental issues. Disease burden can be expressed in *Disability-Adjusted Life Year* (DALY), combining the burden due to death and disability in a single index. Using such an index allows the comparison of the burden due to various environmental risk factors with other risk factors or diseases. It also allows forecasting the possible impact of policies and preventive actions.
For noise, estimates of the burden of disease (BoD) were reported in the Netherlands and Switzerland. However, there is little international agreement on the health end points and the method of estimation.

WHO Headquarters has been synthesizing the available evidence for quantifying disease from different environmental risks since 2003. In 2003 Dr Augustinus de Hollander has produced a first draft for environmental noise in cooperation with WHO to assist countries in estimating their disease burden at national or sub-national level due to environmental noise.

The document produced by Dr de Hollander was peer-reviewed and it was concluded that the document needed more expert input. In addition it was concluded that the recent studies performed on cardio vascular diseases and sleep disturbance should be included. Therefore the noise unit of the WHO EURO European centre for environmental and health, Bonn office, with the cooperation of the German Ministry of Environment, the German Ministry of Social Affairs and the Swiss Agency for the Environment, Forests and Landscape started this project in 2005 and organized this expert consultation.

The meeting

On the 23rd and 24th June 2005, in the premises of the "Regierungspräsidium" - District Government of Stuttgart, a group of international experts met to draw a consensus on the methods of assessing the BoD related to environmental noise. This workshop was co-sponsored by the Baden-Württemberg State Health Agency and by the German Ministry of Social Affairs.

The objectives of the meeting were to:
- Establish a method for estimating disease burden of noise at national/local levels
- Define the health effects to be considered and their severity weights
- How to overcome the lack of data on the exposure side

The meeting was split into five sessions:
- Methodology,

- Country approach,
- Health outcomes,
- Exposure assessment,
- General discussion

Experts exchanged opinions on general and specific issues, which led to conclusions and recommendations as a consensus of meeting participants. This report and the background information distributed at the workshop, such as draft papers, and presentations, are accessible on the World Wide Web (http://www.who.int/quantifying_ehimpacts /national/en/index.html). This report summarizes the discussions and recommendations of the workshop for use by WHO and other stakeholders, Member States and donors, to follow up the progress of the project.

Conclusions and recommendations

- For every outcome the existing evidence and the methodology used to assess such evidence should be clearly outlined;

- Although annoyance surveys show some differences between countries, the differences are very small and not worth being considered. One single dose-response curve for Europe is valid;

- The evidence (AF, RR, etc) to be used is the one resulting from solid studies evidence (meta-analysis or literature reviews according with the WHO publication "Evaluation and use of epidemiological evidence for environmental health risk assessment" - WHO guideline document - WHO European Centre for Environment and Health, Bilthoven Division, A. van Leeuwenhoeklaan 9, Bilthoven, The Netherlands);

- The document should be organized in a way that if the health sector wants only the "core" of disease it can be extrapolated. In another words, no consensus could be made to consider annoyance as a ill health status;

- Attributable effects can be agreed upon at the international level and others affecting "quality of life" could be defined by the national authorities (e.g. annoyance);

- The health outcomes to be documented are hearing impairment, tinnitus, cardiovascular outcomes, sleep disturbance, indirect effects - injuries and cognitive development impairments. Annoyance will also be covered in a specific chapter;

- Each health outcome will be of assigned to a different expert who will produce the section for that effect (define heath outcome, define measure of exposure, synthesise the evidence, propose exposure-risk relationships and define the outcome) according to the terms of reference to be produced by WHO;

- For deriving the severity weight expert opinion will be used;

- If a specific outcome does not have already an attributed severity weight on WHO catalogues, the responsible expert will propose it. After it being peer reviewed it will be used. Guidance will be given by WHO for covering all important aspects;

- WHO should update its catalogues when a consensus is reached on the severity weights;

- For the second project meeting in December, a preliminary spreadsheet should be prepared for each outcome along with the exposure data of the selected Member States to calculate the EBD.

Follow up actions

The health outcomes due to environmental noise and expert(s) responsible for estimating specific BoD corresponding to them are:

- Injuries – Dr Jovanovic
- Cognitive development impairments – Professor Hygge, Dr Klatte
- Hearing loss – Professor Prasher
- Tinnitus – Dr Deshaies, Professor Zenner
- Cardio-vascular disorders – Dr Babisch
- Sleep disturbance – WHO noise unit, RIVM (existing document)
- Annoyance – RIVM (existing document)

WHO will produce detailed terms of reference for each outcome. Common issues to be covered are the following.

Common issues to be considered by experts:

1. Cross – cultural applicability
- Is it likely that the exposure-response relationship is cross-culturally applicable?
- Is the literature available for various cultures?
- Is it, for any reason, plausible that the exposure-response relationship is different for different countries? Special attention should be paid to the developing countries.

2. Relative versus absolute estimation of risk
- Does the literature contain both relative (i.e. relative risk, odd ratio) and absolute measures of risk (e.g. number of cases at a given level of exposure)?
- If yes, the choice of one or the other should be debated.
    NOTE: Relative measures of risk are generally preferred if the risk acts in
    conjunction with other risks at the same health outcome.

3. Synthesis of the evidence (following the WHO guidance document Evaluation and use of epidemiological evidence for environmental health risk assessment):
- Quality of studies (study design, control for confounders, etc)
- Reliability and consistency of evidence for consideration of causal association

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Examples of outcome-specific issues

SLEEP DISTURBANCE

1. Define the relevant measure of exposure

2. Definition of outcome
Use as outcome measure the WHO case definition of primary insomnia, and try to match the exposure – response relationship to the WHO case definition which severity weigh is 0.1.

3. Synthesis of the evidence base
- considered as strong enough (or sufficient) for quantification of the health effect

4. Recommend exposure – response relationship

INJURIES

Linkage between noise and accidents

Noise exposure	**1** →	Sleep disturbance (or other measure of impact on sleep)	**2** →	Accidents

Case definitions must match
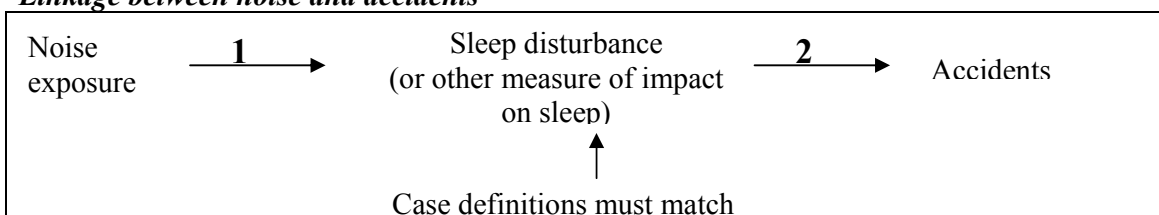
1. Define measure of exposure, sleep disturbance, and accidents

2. Synthesis of the evidence base of pathway 1
- considered as sufficient for causality and quantification of disease

3. Recommend exposure – response relationship for pathway 1

4. Synthesis of the evidence base of pathway 2
- considered as sufficient

5. Recommend exposure – response relationship for pathway 2

6. Recommend overall exposure – response relationships between noise exposure and accidents (road traffic and occupational accidents, falls and other - ICD codes matching these categories can be provided by WHO if necessary)

NOTE: The measure, or case definition, of sleep disturbance (or insomnia) which is selected as the outcome of pathway 1 has to match with the input to pathway 2.

CARDIOVASCULAR DISEASES

1. Define measure of exposure

2. Definition of outcomes

3. Synthesis of the evidence base

- considered as sufficient in terms of causality and for quantification of outcome

4. Recommended exposure – response relationship for quantification of outcome

HEARING LOSS

1. Define measure of exposure

2. Definition of outcomes
The following outcomes are recommended, as they already have severity weights by WHO.
- Binaural pure-tone average for the frequencies of 1000, 2000 and 4000 kHZ of greater that 25 dBHL
- Permanent unaided hearing threshold level for the better ear of 41 dBHL or greater for the four frequencies 500, 1000, 2000 and 4000 Khz.

Otherwise use an outcome that can be converted to any of the 2 measures above (see EBD series, No. 9, Section 5).

3. Synthesis of the evidence base
- Considered as sufficient in terms of causality and for quantification of health outcome.

4. Recommended exposure – response relationships

Highlights of the meeting sessions

Introductory remarks

There were four welcoming speeches from the hosts of the meeting. Mr Kreuzberger from the District Government "Regierungspräsidium Stuttgart", Dr Lichy and Dr Wuethe from the Ministry of Social affairs and Dr Bittighofer from the State Health Agency of Baden- Baden-Württemberg. They welcomed the participants to the District Government Stuttgart and the city, emphasized the importance of noise to the region and praised the cooperation between WHO and the State Health Agency of Baden-Württemberg.

Mr Bonnefoy thanked the hosts and explained the project in detail. The EBD methodology was developed by WHO HQ and many European countries use it for health impact assessment. This community noise project was initiated in 2001 with a first draft by Dr de Hollander.

Methodology

Assessment of environmental burden of disease (EBD), Dr Annette Prüss-Üstün, WHO HQ

Dr Annette Prüss-Üstün, from WHO headquarters, made the first presentation on the topic: "Assessment of environmental and burden of disease (EBD) introduction and methods". She described the methodology, the reasoning and the major principles of EBD calculation. Her presentation is attached on annex 2.

Environmental Burden of Disease is the quantification of health impacts caused by various environmental risk factors at population level, using a comparable framework, definitions and outcome measures. It provides an important input to the rational development and evaluation of

policies by the health sector and activities of other sectors which directly manage or influence the determinants of health.

The resources for prioritizing actions aiming at improving health and health-supporting environments are limited, and EBD is a valuable tool countries can use. It uses a common "health unit" and compares various risk factors and diseases and the situation with other areas. It supports to monitor progress. It points to vulnerable population subgroups, could be used as a basis for cost-effectiveness of interventions and in addition it shows the high preventive potential of environmental health action.

WHO has analysed global health impacts from 26 major risks to health, including selected environmental risks in 2002 and has been developing a series of guides for EBD assessment to assist countries in estimating their disease burden at national or sub-national level. To this date twelve have been published, one is in press and five are in preparation (full list in annex 2). All guides have been developed by large networks of experts and methods have been peer-reviewed.

Quantifying disease from health risks generally requires the distribution of exposure to the risk factor, exposure-response relationship and the relevant health statistics. The basic approach for estimating the EBD is common to every environmental risk factor, however the calculations may vary according to the information available in the country, and the form in which this information is held.

The distribution of the exposure in the population and the exposure-response information are combined into an impact fraction, which is applied to the disease estimates. The impact fraction is the percentage of the population risk that can be attributed to hazardous exposures or risky behaviours, multiple levels of exposure, or to incomplete elimination of exposure. When exposure is measured in terms of increasing levels, the approach is called an exposure-based approach.

The exposure variable needs to be carefully selected, according to the following criteria:

- It should be possible to measure or estimate the exposure variable for larger population groups

- The exposure variable should match the variable used in available exposure-risk relationships.

EBD can only consider outcomes for which not only the causal link has been established in the literature, but also for which quantitative evidence is available. Equally, the choice of outcomes that can be quantified also depend upon the available evidence. Generally, only health outcomes (such as ischaemic heart disease, insomnia) are being assessed. It is however possible to assess other indicators such as annoyance, which would however be qualified as burden (or impacts) rather than disease burden.

Exposure and exposure-risk relationships are combined into an attributable fraction, which has yet to be multiplied against a measure of health of the concerned disease in order to result in a quantified measure of attributable disease. This measure should also reflect the measure used in the exposure-risk relationship (generally mortality or incidence). It is however possible to use an additional health metric which combines mortality and morbidity. Such a measure presents the advantage that the occurrence of diseases can be more easily compared between each other, and

that diseases with comparatively low mortalities but a high burden, such as some neuropsychiatric diseases or hearing loss, can nevertheless be adequately represented.

The most commonly used measure is the Disabilty-adjusted Life Year (DALY). Besides the DALY, several other such measures have been devised, including the Quality-Adjusted Life Year (QALY), the Disability-Adjusted Life Expectancy (DALE), the Healthy Life Expectancy (HALE) and the Healthy Life Year (HeaLY). The benefits and challenges of these measures have been widely examined and debated, but the underlying concepts of the various measures are similar.

The DALY measures health gaps as opposed to health expectancies. It measures the difference between a current situation and an ideal situation where everyone lives up to the age of the standard life expectancy, and in perfect health. It combines in one measure the time lived with disability and the time lost due to premature mortality (DALY = YLL + YLD, YLL = years of life lost due to premature mortality and YLD = years lived with disability).

The YLL metric essentially corresponds to the number of deaths multiplied by the standard life expectancy at the age at which death occurs, and it can be rated according to social preferences. YLDs measure the incidence of disabilities and the average duration of each disability. The product of the incidence and the duration will then provide an estimate of the total time lived with disability. To estimate YLD on a population basis, the number of disability cases is multiplied by the average duration of the disease and a weight factor that reflects the severity of the disease on a scale from 0 (perfect health) to 1 (dead).

To place a value on the time lived in non-fatal health states, health state (or disability) weights are used to formalize and quantify social preferences for different states of health. Such weights have been developed basically on the basis of consultations of groups of health experts. In addition, the DALY takes into account various societal choices, including discounting of good health with time and higher valuation of a lost year of healthy life at some ages (YLLs in adults in productive age are generally valued higher than at younger or older ages).

Country approach

Canada - The Canadian Methodology for assessment of the burden of disease - Dr Christel Le Petit, Statistics Canada

Dr Le Petit made an overview of the Canadian project on burden of disease for cancer. The methods, results and some practical aspects were presented.

In the context of the Canadian Burden of Disease Study, a report for the Auditor General for population health in 2001 was made. This study was carried out by the Statistics Canada and the Public Health Agency of Canada and its main goal was to establish a population health impact programme.

They modified the WHO methodology for Burden of Disease calculation by using Health Adjusted Life Years (HALY) based on YLL and YERF (Years Equivalent of Reduced Functioning). The following formula was used:

HALY = YLL + YERF   (YLL: Years of Life Lost)

For calculating the years of life lost the mortality rates by cause, population counts and life expectancy were used. For calculating the population attributable fractions, they used relative risks and prevalence. For calculating the years equivalent of reduced functioning the incidence and severity, preference scores, durations, treatment, remission and case-fatality were used.

For attributing severity weights, 17 groups were formed with lay Canadians. Thirteen groups did the standard gamble groups (4 French, 9 English). The other four groups addressed co-morbidity and tested time trade-off.

For estimating the risk factors, the "After the fact" approach was used. The Population Attributable Fraction (PAF) was calculated for each of the risk factors, for each disease, using the prevalence of exposure to the risk factor (P), the relative risk of the exposure for each disease was compared to the non-exposed group (RR).

For selecting the relative risk, the criteria were set up. In the best case scenario, all studies would show a similar relationship. When the relative risks are different a meta-analysis was performed. When the data are sparse, it was decided to wait for more studies, to conduct new studies, or to use expert judgement.

In summary, the main differences between the Canadian method and the WHO method are the use of Health Adjusted Life Years in place of DALY, and the selection of the severity weights by the lay population. The Canadian experts did not really worry about international comparison. In Dr Christel opinion, for international comparison, expert judgement is better than lay population at selecting the end points and severity weights.

The Netherlands - Noise-related burden of disease in the Netherlands, - Ms Anne Knol, National Institute for Public Health and the Environment (RIVM), the Netherlands

Ms Anne Knol presented the project the Netherlands is presently carrying out - "Trends in the environmental burden of disease in the Netherlands 1980 – 2020". This project will calculate the DALYs (Disability Adjusted Life Years) in the Netherlands for air pollution (PM10 and ozone), noise, radiation (radon and UV) and indoor dampness. The full paper describing the method and assumptions in detail is annexed on annex 2

For noise the outcomes considered were severe annoyance and sleep disturbance, noise exposure leading to hypertension, and hence cardiovascular diseases, potentially resulting in death, although the exposure-response relationship between noise exposure and cardiovascular mortality is still being debated (Van Kempen et al., 2002).

For calculation of the noise exposure of the Dutch population, the EMPARA model has been used, which uses characteristics of the noise sources to calculate noise emissions and generate noise maps. These emissions are then translated to human noise exposure, using noise propagation paths and demographic data.

People exposed to noise levels between 45 and 75 dB(A) were considered for estimating severe annoyance, for sleep disturbance people above 45 dB(A) were considered, and for hypertension people exposed below 55 dB have not been included on the calculations.

The prevalence was estimated indirectly. In contrast to other health outcomes, by definition there is no base prevalence for noise annoyance or sleep disturbance. The prevalence of noise annoyance and sleep disturbance was estimated using exposure-response models based on combined results from various studies. Another option to estimate the prevalence of annoyance and sleep disturbance is by directly using numbers from surveys. The number of people reporting annoyance in surveys is generally higher. The discrepancies will be addressed in the final report where the outcomes will be compared.

Exposure-response curves indicating the percentage of people (severely) annoyed or sleep disturbed at certain noise exposure levels have been derived by Miedema et al. They have been derived for road, rail and air traffic noise and severe annoyance, and road and rail traffic noise and severe sleep disturbance. These relationships are based on combined results from various studies, which are mostly based in surveys asking people on the manifestation of these effects during the last 12 months. The duration of exposure considered for annoyance and sleep disturbance for DALYs calculation was therefore one year.

The exposure-response relation for noise and hypertension is based on a meta-analysis (Van Kempen et al., 2002), which was based on data for air traffic (RR5 dB(A) = 1.26 (1.14 - 1.39). In this study, the results for air were extrapolated for road and rail traffic noise, which may result In an overestimation of the results. The relative risk for hypertension based mortality is estimated to be 1.4 (1.2-1.6) .

The prevalence of hypertension is estimated to be 24% in men and 19% in women in age category 20-60. For older people, these percentages are higher (RIVM, 2004a). These prevalences have been corrected for population size, but not for composition of the population (ageing).

For the loss of life expectancy DUE TO the cardiovascular outcomes, noise-induced hypertension, leading to cardiovascular disease-related in mortality, was estimated. The average loss of life expectancy due to cardiovascular disease (almost 11 years) was used from mortality tables.

Severe annoyance and sleep disturbance are hard to weigh, because there is little information on their relationship with quality of life measures. A severity factor of 0.02, with a relatively large uncertainty interval (0.01-0.10 for annoyance, and 0.01-0.12 for sleep disturbance) was used. The minimum value (0.01) is based on De Hollander et al. (1999), who used a panel of environment-oriented physicians to attribute severity weights to various health states based on a protocol by Stouthard (1997). The maximum values (0.10 and 0.12) are based on Van Kempen (1998) who did a panel study with 13 medical experts, also based on a protocol by Stouthard. In that study, sleep disturbance and annoyance were weighted relatively high. Since the weight factors are so small and the population exposed very large, the relative variations have a relatively big impact on the estimations.

Annoyance and sleep disturbance manifest at lower noise levels; therefore due to the large number of people exposed to noise in the Netherlands, the majority of DALYs is attributable to these two effects. However 110,000 to 270,000 people may have hypertension which can be attributable to noise exposure in the year 2000. Hypertension can potentially lead to cardiovascular disease. It was estimated that around 600 people may have died due to noise induced cardiovascular diseases in the year 2000, accounting for around 400 DALYs per million people.

Alternatively, noise-related annoyance and noise-related sleep disturbance using prevalence estimates from a recent survey on environment-related annoyance and quality of life (Franssen et al., 2004) were calculated. These results vary greatly from the results based on the exposure-response relationships derived by Miedema et al. (2001). The following table shows the results of the two methods.

		Miedema exposure-response curves (Miedema, 2001), year 2000	Environment-related annoyance and quality of life survey (Franssen 2004), year: 2003
Severe annoyance	Road	1,122 (441 – 2,753)	7,604 (3,119 – 18,387)
	Air	16 (6 – 38)	314 (129 – 761)
	Rail	65 (24 – 158)	524 (215 – 1,268)
Severe sleep disturbance	Road	526 (189 – 1291)	3045 (1,298 – 7,029)
	Air	-	761 (324 – 1,757)
	Rail	32 (10 – 80)	253 (108 – 586)

DALYs for severe noise annoyance and severe sleep disturbance, based on exposure-response curves (Miedema,2001) and based on a survey (Franssen et al., 2004)

For a better understanding of these figures the paper should be consulted (annex 2).

Switzerland - Determining disability weights for quantifying the Swiss Burden of Disease due to noise-related health effects, Dr Ruedi Müller-Wenk, Institut fur Wirtschaft und Oekologie, Universität St.Gallen

Dr Mueller-Wenk presented the work he has carried out to calculate EBD of road traffic noise in Switzerland. In 2002, a document called "Attribution to road traffic of the impact of noise on health" was published. Sleep disturbance was considered as the main night-time health effect of road traffic noise, and communication disturbance as the main day-time health effect. The contribution of Dr Mueller-Wenk is presented on annex 2.

The empirical data supporting the dose-effect relationships were derived from a social survey carried in 1991 – "Swiss noise study 90" with 2052 participants.

There were no WHO disability weights established for sleep disturbance or communication disturbance. But the publication of Murray et al. supplies a method to determine missing disability weights. The procedure adopted in Switzerland to establish the required disability weights (DW), followed the suggested method.

In 2000 a written survey was performed with the 64 members of the medical staff of SUVA (the Swiss Accident Insurance Institute) of whom 16 were physicians from the organisation's central department of Accident Medicine, 15 were physicians from the central department of Occupational Medicine, and 33 were District Medical Officers of Health (*Kreisärzte*) working throughout Switzerland. A total of 42 completed questionnaires were returned, of which 41 were usable.

The interpolation exercise resulted in an average disability weight of 0.055 for noise-related sleep disturbance and of 0.033 for communication disturbance.

The Swiss Burden of Disease due to perceived sleep disturbance caused by road noise was calculated by multiplying three terms: 1. the number of persons exposed to a certain night-time noise level. 2. The percent of affected persons at this noise level. 3. The mean disability weight for perceived sleep disturbance.

For Switzerland's population of 7.2 million inhabitants of year 1995, this resulted in 366,000 cases of perceived sleep disturbance, or 20,160 DALY. This figure is on the order of magnitude as the burden of disease originating from the 664 mortal road accidents in the same year 1995.

It can be expected that the order of magnitude of the road-noise-related burden of disease stays at the same level if the DALY values due to the remaining health effects are added. Therefore for having an approximate estimation of the Burden of disease, it appears to be sufficient to concentrate on sleep disturbance because it is expected that it will give the largest DALY contribution.

Dr Müller-Wenk has advised the group (and WHO), for taking some points into consideration when producing the EBD document for noise:

1) Consider the uncertainty on estimating the number of people exposed to be used on exposure-response curves due to the fact that the noise exposure is measured outside buildings;

2) Describe the health end points in a standardized way in order to compare with other outcomes listed in existing DW catalogues;

3) An international meeting should be organised by WHO, according to the Murray protocols and methodology for fixing the additional DWs by interpolation between existing DWs in particular sleep disturbance, hypertension, communication disturbance (also called interference with speech communication), and increased blood lipids. At present the existing catalogues don't include them.

Discussion
Dr Annette Prüss-Üstün, informed the group that insomnia has a severity weight attributed on the existing catalogues. The question of noise categories has also been raised, the effects are different according to the noise level experienced so the noise levels have to be taken into consideration as well. She also volunteered to support the group on supplying the relevant data by making the link with WHO HQ.

Norway – economic approach -The socio-economic impact of noise - A method for assessing noise annoyance - Truls Gjestland, senior scientist, SINTEF ICT, Trondheim, Norway

Dr Gjestland presented the method Norwegian authorities have developed and adopted for assessing the magnitude of the noise impact in quantitative terms. The method takes into account all levels of annoyance experienced by people living in noisy areas, and transforms these data into a single quantity that can also be expressed in monetary terms. His full paper is on annex 2.

The subjective annoyance caused by a certain noise exposure was scored on a linear scale, zero to one, where "zero" indicates no annoyance at all and "one" is the most extreme annoyance one can imagine.

Results from social surveys on noise annoyance demonstrate that the annoyance score correlates with the noise level expressed in the energy equivalent index. In addition, for a given value of Lden, noise from rail traffic is less annoying than noise from road traffic, which in turn is less annoying than aircraft noise. In connection with environmental noise this fact is often referred to as *rail bonus* and *aircraft malus* with respect to road traffic noise.

The dose-response functions for transportation noise (Miedema et al), are a set of nearly parallel lines spaced approximately 6 dBA apart.

Numerous attempts have been made to calculate a "cost" or to set a "price" on community noise annoyance. Factors that influence this "price" include for instance:
   • psychco - physiological effects, stress, etc.;
   • sleep disturbances (and resulting productivity loss);
   • communication problems;
   • (possible) hearing damage.

The "price" of annoyance is likely to be reflected in a depreciation of property values, and studies have validated this hypothesis. There is a linear relationship between the noise level and a change in property value (in Norway roughly 0.5 % pr dBA), being the change in value per decibel independent of the absolute level (ref: European Conference of Ministers of Transport).

A similar relationship has been found for the annoyance score. A given change in the noise exposure is related to a certain change in the annoyance score regardless of the absolute noise level or degree of annoyance a person is exposed.

The magnitude of the noise impact in a certain area can therefore be defined as the sum of the annoyance scores experienced by all the residents within that area. This quantity is referred to as the noise annoyance index (in Norwegian: SPI = støyplageindeks). The unit 1 SPI equals "one extremely annoyed person". It can be argued that this quantity is a better predictor of the noise impact than for instance the percentage highly annoyed which is commonly used, as the annoyance index also takes into account the annoyance experienced by all the persons that are annoyed to a lesser degree than "highly". A large number of people can be annoyed, but not necessarily highly annoyed. The SPI quantity also includes these groups.

In Norway the "cost" of one extremely annoyed person (1 SPI) has been estimated to be approximately 1600 Euros per year. Due to the linearity explained above, the "cost" of a moderately annoyed person (0.5 SPI) thus equals 800 Euros per year etc. (Norwegian Pollution Control Authority, report 1714/2000).

As an example the total "cost" of the annoyance caused by road traffic noise in Norway has been estimated:

Noise level, Lden	Annoyance score	Number of people	SPI
50 - 55	.207	600000	124200
55 - 60	.286	412000	117832
60 - 65	.365	385000	140525
65 - 70	.444	205000	91020
> 70	.523	57000	29811
sum		503388	

The annoyance index, 535,778 SPI corresponds to a cost of more than 800 million euros. This relationship can be used for cost-benefit calculations. The national target for a reduction of community noise is a 25 % cut in the annoyance index.

Health Outcomes

During this meeting presentations were made for the following health outcomes:
- Tinnitus;
- Cognitive impairment in children;
- Annoyance;
- Sleep disturbance;
- Mental health;
- Indirect effects – accidents resulting from sleep disturbances;
- Cardiovascular effects;
- Hearing impairment.

Prevalence of tinnitus in Quebec - Dr Peter Pierre Deshaies – WHO-PAHO Collaborating Center, Institut national de santé publique du Québec (INSPQ)

Dr Deshaies presented the Quebec "1998 Health and Social Survey" results on hearing impairment and tinnitus (presence, frequency and severity of the problem). This was the third time this survey was made (1987, 1992-1993), but the first time it considered tinnitus. It covered 12 000 representative private households, with a target population of 97,3 % of Quebec's total population. People living in chronic care facilities or hospitals were not surveyed.

The questionnaire had altogether over 400 questions, and the global response rate was 82%. The survey covered demographic and socioeconomic aspects, physical health (including tinnitus), mental health, social network, lifestyle, work and some work-related exposures and problems and use of health services. This was the first time population data was collected in Quebec for tinnitus, and the results are comparable to surveys in other countries.

Tinnitus is a serious problem. In the literature tinnitus is described as being a cause of reduced quality of life, anxiety, sleep disturbance and it can lead to depression and lack of concentration.

The results of the survey showed that, among those declaring having tinnitus in the 15 years old or older population group 18,9% often have tinnitus and 16,4% always have it, these percentages generally increasing with age, except for the 75 years old and older group. This translates in 2,1% of the population aged 15 or older who report always having tinnitus and 1,3% declaring that it bothers them a lot. These results are comparable to surveys in other countries.

Overall, 41% of individuals with tinnitus consulted a health professional. However 25% of individuals with tinnitus never consulted a health professional. This is considered a quite low rate of consultation for that latest group, showing that the magnitude of the problem can be greater than what is seen by health professionals.

The experts analysed the data in order to explore the relationships between noise and tinnitus. It has been reported in scientific literature that exposure to intense noise is associated with tinnitus (Pilgrimm 1999, NIH 1990, both *in* Paré 2000). However, an association was not observed in this survey. This is probably due to the fact that good exposure data is lacking – the questions were about tinnitus lasting for more than 5 minutes at a time, with no reference to specific causes. Also there was no question on environmental noise exposure, as respondents were only

questioned for noise exposure in present job activities (therefore, at the moment of survey with no reference to exposure duration).

There are a lot of unanswered questions regarding tinnitus: What does temporary tinnitus means in terms of health impact? What is the minimal duration of temporary tinnitus that can lead to permanent? What is the minimal duration and intensity of noise exposure leading to it?

Therefore a question was raised to the group at the end. For calculating the Burden of Disease of noise-induced tinnitus what data should be used? Results from literature? Should special surveys be carried on?

Discussion
The discussion that followed this presentation stressed the fact that, indeed, the mechanisms behind tinnitus are still unknown. The way it is triggered is still not fully understood. Further research is needed. However this will be further developed, and if possible included in the final document.

Cognitive impairment in children due to noise – Professor Hygge

Professor Hygge covered the topic – "cognitive impairment on children due to noise". He was requested to make a literature review and present the evidence for the effects of noise on the cognitive development of children. Professor Hygge's contribution is attached in annex 2.

A general finding in existing studies of the effects of noise on cognition and human performance has been that, the noise levels have to be high to produce a reliable effect, however, the problem can be approached the other way around – by analysing the relative gain in cognitive performance by lowering the noise.

Attentional tasks generally have shown a fairly high resistance to noise exposure. Often no impairment is reported with increased noise levels (Cohen, Evans, Stokols & Krantz, 1986). Notable exceptions are Hockey (1973) who showed more selectivity (approx. 12%) under noise (100 dBA) than in quiet (70 dBA) in a paced task.

Memory and reading have also been studied in some field studies with children. In the Munich airport study (Hygge, Evans & Bullinger, 2002), children improved their long-term recall memory by approximately 25% when the old airport was closed. At the new airport the recall memory deteriorated by approximately to the same amount of the old airport. The change in L_{Aeq} noise levels at the old airport from before to after was around 14 dBA. At the new airport the change was around 9 dBA. For the children's reading tasks in the Munich study the results were similar to those for recall, i.e. improvements when the old airport closed and impairments when the new airport opened.

The Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health (RANCH) study, the largest cross-sectional study of noise and children's health, examined 2844 children 9-10 years old from 89 schools around the airports in London, Amsterdam and Madrid (Stansfeld et al., 2005). The results indicated impairment from aircraft noise, but not from road traffic noise, on reading comprehension and recognition memory, but not on recall. A 5dB difference in aircraft noise was stated to be equivalent to a two-month reading delay in the UK and a one-month reading delay in the Netherlands.

Several well-replicated studies have shown that performance is impaired if speech is played back while subjects read and memorize verbal material (see Tremblay, Nichols, Alford & Jones, 2000). This effect of irrelevant speech was rather independent of its intensity, and has been reported from noise levels below 60 dBA. The meaning of the speech also seems to be unimportant, since the negative effect has been found with foreign languages, backward speech, as well as non-speech signals that have an acoustical variation in the signal that is similar to natural speech. This negative effect of speech and speech-like sounds seem to be on memory rather than on perception.

However, most of the research on irrelevant sound and speech has employed a serial short-term memory recall task, and the pronounced negative effects seem to be more marked for serial recall tasks than for non-serial memory tasks.

Exposure-effect curves can be derived from these studies. The studies on recall and reading cluster together and have slopes around 2% per dB. Studies on recognition and attention also group together and have slopes in the region of 0.25% per dB. Thus, for recall and reading in noise it is expected that a reduction of the noise level by 5 Ldn would result in improved performance by something like 10%. For attentional tasks and for recognition memory, a 5 dB Ldn reduction in noise level is expected to only result in 2-3% improvement of the response.

Dr Maria Klatte, Dr Seidel - Noise in the School Environment and Cognitive Performance in Elementary School Children

Dr Maria Klatte from the University of Oldenburg and Dr Seidel from the Institute of Building Physics have presented the Field Study they are carrying out with 520 children of 21 classes in the region of Stuttgart (seventeen on the second-grade, four from the first-grade).

They are investigating the effects of permanent noise exposure on language impairments and reading, spelling and attentional disorders by comparing the children from schools with different acoustic properties.

Annoyance, sleep and mental health – Ms Célia Rodrigues - WHO ECEH Bonn

Ms Rodrigues presentation covered the two well known and consensual noise effects (annoyance and sleep disturbance) and presented the existing knowledge on noise and mental health. She presented the existing evidence on sources, metrics and symptoms, the exposure-response curves (when existing) and vulnerable groups.

Annoyance
If we take the WHO definition of health, noise annoyance can be considered as a health problem. It is estimated that 22% European population is annoyed or highly annoyed by noise.

Exposure-response curves exist and are consensual, being also recommended by the European Commission for MS use. They were derived by Miedema et al. for annoyance and road, rail and air transport noise. They are based in reference studies that dealt with different modes of transportation carried out in Europe, North America, Australia, and Japan and they use the Ldn or Lden or, LAeq24h – levels measured outdoor.

Other noises sources such as neighbourhood noise are much more complex to characterize with a simple noise measurement. For example the simple fact of hearing one's neighbour can in some cases be considered as annoyance!

These results seem to be applicable in developing countries, although in these countries very often noises of very high intensity are observed, levels such that the percentage of people annoyed would be close to 100%.

An ageing factor exists for annoyance - studies have proven that annoyance increases from 18 years old and up having the highest rate at the age of 50, starting to decrease afterwards. For children a non-linear association with annoyance was found for children and aircraft noise (RANCH study, 2005). In the RANCH study increasing exposure to both aircraft noise and road traffic noise was associated with increasing annoyance responses in children.

Sleep disturbance
Sleep disturbances are frequently considered as the most accurate and predictive consequences of environmental noise on health.

There are different methodologies to assess sleep disturbance;
- Subjective sleep disturbance reports;
- Behavioural awakening measures;
- Indirect sleep disturbance measures (body motility, for instance);
- Actual sleep recording and sleep stage scoring;
- After-effects (short and long term effects).

To some degree, sleep disturbance by noise may be quantified by:

Effects on sleep structure:
- Delay on sleep onset;
- EEG arousals;
- Sleep stage changes;
- Awakenings;
- Modifications of temporal structure of sleep;
- Time spent in the different sleep stages;
- Premature final awakening.

In complement, concomitant modifications in the autonomic functions (heart rate, blood pressure, vasoconstriction and respiratory rate) could be indicative of the reactivity of the sleeper.

The main consequences of sleep disorders include physical effects (day-time sleepiness, fatigue, ability to maintain a healthy endocrine and immune system) and psychological effects (deterioration of performance, reduced attention and motivation, diminishment of mental concentration and intellectual capacity). Sleep disorders have an impact on quality of life and on professional and personal behaviour on education, absenteeism, risk of traffic, work and domestic accidents.

There is a rather weak overall agreement about exposure - response relationships of noise and sleep disturbance as the scientific literature indicates. Dose-effect curves exist for subjective reporting (next day surveys), motility and behavioural awakenings. The subjective complaint of

bad sleep can be reported in the following morning either spontaneously or in response to specific questions. But these are not considered by sleep specialists to be the best way to assess sleep disturbances, subjective estimates and objective measures of disturbed sleep are often not superimposed. For example the sleep apnoea syndrome (SAS) patients often consider that their sleep is of rather good quality, even if it is restless.

There are still open questions regarding how to design objective measures of sleep disturbance, in terms of arousals and probability of inducing a sleep stage change, even if there is clear evidence of cases where no objective noise effect is accompanied by loud complaints, and cases where people do not complain about the noisy environment and still exhibit clear sleep and/or cardiovascular modifications on the long term. In a recent field study for aircraft noise (Passchier-Vermeer et al., 2002)) an increased probability of instantaneous motility was found for events with a maximum sound level LAmax>32 dB (A), while in a meta-analysis, conscious awakening was found for events with LAmax >42 dB(A) (Passchier-Vermeer et al., 2003). In a recent field study, threshold for EEG awakening was found to be LAmax = 35 dB(A) (Basner et al., 2004).

Above their threshold (indoor level in the sleeping room), these effects were found to increase monotonously as a function of the maximum sound level during a noise event

The Lden (day-evening-night) is a good metric of assessing the global noise exposure, while event indices are more accurate to predict sleep disturbance. A large review of the literature shows that it is generally acknowledged that measures of peak sound level are better predictors of disturbances in sleep than measures of average sound level.

The possible risk groups to noise can be people reporting sensitiveness to noise, shift-workers and night-workers. People sensitive to noise normally complain and protest more against noise. In the laboratory studies found that 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. Possible risk groups for having their sleep disturbed by noise are:

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.

Regarding cardio vascular responses during sleep[1,] a certain degree of habituation to noise does exist. But this habituation is not complete and the measured modifications of the cardiovascular functions remain unchanged over long periods of exposure time. 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 (Hofmann et al., 1995).

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[1] Dr Wolfgang Babisch will cover these aspects

These effects are observed at lower noise levels than when awake, but still little is known about their significance.

Insomnia may be considered as a proxy of sleep disturbances caused by noise. The long term effects of insomnia are not completely understood by sleep specialists. However it seems that chronic insomnia is associated with behavioural impairment (fatigue, poor performance at work, memory difficulties, concentration problems, car accidents), psychological (depression, anxiety, alcohol and other substance abuse) and medical (cardiovascular, obesity, endocrine impairment, pain, impaired immune system).

Exposure - response relationships exist for self reported sleep, motiliy and awakenings. 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. Motility is related to many variables of sleep and health (Reyner, 1995; Reyner and Horne, 1995; Patterson et al., 1993, Passchier-Vermeer et al., 2002). Clinical research shows that the sleepwake 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; Cole et al., 1992, 1995). 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.

Mental health

Current evidence suggests that environmental noise exposure, especially at higher levels, is related to mental health and possibly raises anxiety and consumption of sedative medication, but there is some evidence that it has more serious effects. 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, socio-economic deprivation, and psychiatric disorder. It is also possible that people underestimate or minimise the effects of noise on health through optimism bias (Hatfield & Job, 2001) and that this is particularly protective for mental health.

The evidence is not strong for the association between noise exposure and mental illness. Noise exposure may be responsible for psychological symptoms above 70 dBA Leq. Almost all studies have only examined the effects of day-time 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 day-time noise.

The evidence is strong on mental health effects due to 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.

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 starts first.

Noise sensitivity can be related to anxiety; anxious persons are more sensitive and have less capacity to adapt to a situation. A person already suffering from mental health problems (such as anxiety, depression or paranoia) will be more vulnerable to noise than a healthy one.

Accidents resulting from sleep deprivation and mask effects – Dr Snezana Jovanovic

Dr Snezana Jovanovic conducted a literature review on the increased probability of accidents deriving from sleep disturbance. According to sleep literature children with disturbed sleep present cognitive dysfunction and behavioural disturbances, abnormal growth hormone release, increase of diastolic blood pressure, increased risk of accidents and use of sleeping pills *(Bruni, 2005)*.

According to a study (Menchini et al. 1985), childhood accidents occur more frequently during the spring and the summer. Falls, cuts and laceration, unintentional ingestion, pedestrian injuries, burns and scalds, choking episodes and animal related injuries are the most common types of injuries, and also the most likely linked to sleep disturbance in young children. Results suggest that children with more frequent injuries had significantly more sleep problems. And that there is an increased prevalence of sleep disturbances in preschoolers with increased injury rates.

Results of a study on sleep disturbance and injury risk in young children show that inadequate sleep duration and lack of day-time naps are transient exposures that may increase the risk of injury among children. Among children (boys particular) from 3 to 5 years of age, 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, irritability and moodiness (Fallone et al., 2002)

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

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

The biggest industrial catastrophes like the Three Mile Island, Bhopal, Chernobyl and Exxon Valdez disaster occurred during the night shift. The shift schedules, fatigue, and sleepiness were cited as major contributing factor to each incident.

The LARES (Large Analysis and Review of European housing and health Status) study 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 reported having their sleep disturbed during the previous 4 weeks.

Dr Jovanovic concluded, at the end of her presentation, that she considers the data available to document the impact of environmental noise on sleep deprivation and accidents is largely

inadequate to use, at this stage, on the EBD document. She is of the opinion that the estimates should be improved by studies and epidemiological work. There are 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.

Discussion

The group reacted strongly to the presentation's conclusions and supported that an attributable fraction could be derived from limited evidence. There are some other fields where the evidence is lower and still is consensually accepted. The correlations can be calculated with a strong remark that the data were extrapolated from sleep studies.

For doing an extrapolation, also some questions have to be addressed: Is the effect of noise on sleep similar to the ones that have proven to cause accidents? What is the effect of duration of disturbance (or sleep deprivation) on the incidence of accidents?

Studies should be carried out to further investigate these issues; however caution has to be paid when doing them. The accident rate around very noisy areas is probably very high, but the weight of sleep disturbance on it would be very hard to estimate. The problem resides on how to extrapolate the noise fraction, other factors can be the reason behind it (noisy areas places tend to have the worse environmental conditions).

If possible the document should also give some recommendations for future studies on how to assess the problem.

Cardio-vascular effects – Dr Babisch

Dr Babish presented an update of the very comprehensive literature review he had performed for the parallel WHO project Night Noise Guidelines project. His analysis is based on the pyramid of effects, on the NOEL/LOEL concept and on quality of life versus ill health. According to the WHO publication on review of epidemiological evidence, a meta-analysis was carried out for road traffic noise and myocardial infarction.

There is sufficient evidence of an association between road traffic noise and ischaemic heart diseases, and limited/sufficient evidence for an association between community noise and hypertension.

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 a continuous increase in risk with increasing noise level would be expected. However, adaptation, coping and habituation may be reasons for an empirical threshold of effect. Decisions with respect to defining threshold values should be based on a quantitative risk assessment – not ignoring the individual risks of exposed subjects, if considered as relevant.

The paper provided by Dr Babisch is attached as Annex 2. It contains the figures of the attributable risk and of the NOEL.

Environmental noise and hearing loss – Professor Deepak Prasher

Professor Prasher started his presentation with an introduction of the noise sources, the scale of sounds and on the current European Exposure. According to the European Environment Agency

about 450 million people (65% of European population) are exposed to noise levels above 55dBA, which may result in annoyance, aggressive behaviour and sleep disturbance. A further breakdown shows some 113 million exposed to levels greater than 65dBA and around 10 million to noise levels above 75dBA, which can potentially result in increased hearing loss.

A noise level is considered hazardous when communication not possible, (hearing impairment is also considered possible without any significant change in audiometric threshold change) and it can cause:
- Continuous tinnitus;
- Inability to localise sounds;
- Distortion of sounds;
- Asynchrony in timing of information unusually sensitive to loud sounds.

Exposure to loud noise leads to a worsening of hearing sensitivity, ringing noises in one ear or both, either temporarily or permanently. Early signs of noise effects on hearing (including the presence of tinnitus, muffled hearing, distortion of speech, speech recognition in noisy environments, poor sound localisation, intolerance of loud sounds, altered frequency selectivity, altered temporal integration, altered auditory efferent function, loss or reduction in otoacoustic emissions) may provide an alternative to change in audiometric thresholds as measures of the effect of noise on the auditory system.

The auditory effects are:
- Poor Speech Communication in Noisy Conditions;
- Acoustic Trauma: Sudden hearing damage;
- Tinnitus: Ringing in the Ears;
- TTS:Temporary threshold shift;
- PTS: Permanent threshold shift;
- Interference with Communication.

In terms of the noise exposure, different types of noise environments may have similar sound pressure levels and spectra but very different temporal patterns in terms of the distributions of peak noise components. Accurate characterisation of noise has been the major obstacle in relating exposure to effect. The current practice estimates the hearing loss due to noise exposure on the basis of the total integrated level of acoustic energy over a given exposure duration. There are large variations in the responses across individuals to even a very precise noise exposure. Statistical measures of the range of hearing loss on the basis of 8 hour continuous noise exposure for 5 days a week for 40 years may be computed.

A study (Nasser 2001) on Temporary Threshold Shift (TTS) and aerobics and another study on TTS and pop-music have (Hellstrom et al 1998) showed interesting results. With 60 minute exposure to aerobics music (average level 89.6dBA±4.7) a TTS at all frequencies except 1kHz has been found. With pop-Music exposure (level 91-97dB - max 113dBA) a TTS range of 4-16dB was found.

Assuming that loud music exposure has the same effect as industrial noise exposure and using ISO 1999 to estimate noise induced hearing loss, bar staff and DJs show a significant risk of hearing damage with varying severity dependent on duration of service (Smeathan 2002).

A very important exposure to consider is the use of noisy toys by young children. The heads, ears and external auditory canals of children are shaped differently to adults producing a greater amplification of high frequency sounds. High frequency hearing loss in school children has not decreased in Scandinavia although it decreased among industrial workers, and studies show Permanent Threshold Shift in children due to noisy toys, games, fire crackers, and gunfire exposure. There are toys that make sounds on the range 78-108dBA at 10cm, e.g. a model aeroplane at arm's length produces 112dBA and toy mobile phones at child's ear 122dBA. In addition children under 6 years cannot describe hearing loss.

A study conducted on aircraft noise and hearing in school-age children (Chen TJ and Chen SS 1993) with 2 schools confirmed that this source can affect children's hearing. School A was near an airport (n=228) and a school B was far from airport (n=151), the hearing thresholds average, high tone average and 4kHz were all worse in School A compared to School B.

Another study (Axelsson et al 1984) examining the prevalence of hearing loss (20dB at any frequency) in Swedish children found that at the age of 7, 13,7% of boys and 11,7% of girls had hearing loss (beyond the average), for the age of 13, 15,6% of boys and 9% of girls.

Teenagers practice often noisy activities like playing in band, motor sport, going to discos and pop-concerts and shooting (Jokitulppo et al 1981). 51% of teenagers are estimated to be exposed to noise levels detrimental to hearing acuity, having hearing symptoms correlated to noise dose.

A survey in the United Kingdom investigating hearing loss in young people found out that the percentage of young people exposed to potentially dangerous social noise has increased from 7% in the 80s to 23% in the 90s. Another survey in Norway found that in 30,000 Norwegian 18 year olds tested, 15% in the 80s had hearing loss and in the 90s this percentage increased to 35%.

Also tinnitus starts to be reported by young people, in a study (Widen and Erlandsson 2004) of 1285 subjects (13-19 years), 8.7% had permanent Tinnitus and 17.1% were noise sensitive. There is a bigger reporting of tinnitus by older students.

There are however some limitations to use these data, most studies report post exposure hearing effect (TTS and Tinnitus) and there is lack of evidence between TTS and subsequent hearing damage or between post exposure tinnitus and permanent tinnitus. There are difficulties in estimating exposure and also limitations of Audiometry identifying early signs of hearing loss.

A risk assessment for hearing loss needs to consider
- The major auditory hazards of amplified music and traffic noise;
- The implication for young people listening to music, attending discos, night clubs, concerts, bars, pubs etc;
- Those working in noisy jobs or bars, clubs, in traffic etc;
- The potential risk for hearing loss is high through multiple sources of exposure over time (toys, video arcades, clubbing, mega-city living and working);
- Susceptibility issues across individuals make quantification of numbers affected and size of effect difficult to determine.

Exposure assessment

Environmental noise exposure assessment - Dr Jérôme de France

Dr De France presentation covered the following aspects:

- Available data of noise exposure;
- Future data required by the European Commission (Environmental Noise Directive - END);
- Assessment methods of the END and;
- Production of data by Member States

There is some data for EC Member States available on the Green Paper (1996), the EEA TERM report (EEA, 1999) and from a joint OECD/EUROSTAT voluntary survey (Including noise exposure questions) however this data were so poor (1 to 3 MS reply usually) that they are not even checked neither published by Eurostat.

There is some data also published by some European countries.

France has data for road traffic noise – there are 200 000 dwellings exposed to LAeq (8h-20h) above 70 dB(A).

The Netherlands has estimated annoyance and sleep disturbance for road traffic noise - 1,5 to 2 million people annoyed (50% highly annoyed) and 550 000 to 1 million sleep disturbed (50% highly).

In Germany (2000) it was estimated 1800 premature deaths per year (2000) attributable to road traffic noise (coronary thrombosis).

Switzerland estimated 100 premature deaths per year (2000) attributable to noise (coronary thrombosis) and it is estimated that there are 650 000 persons exposed to LAeq(22h-6h) above 55 dB(A).

Denmark *(Danish national noise strategy, national infrastructures)* has estimated that are 706000 dwellings exposed to LAeq(24h) >55 dB(A) of road traffic noise and 200-500 premature deaths (from hypertension due to noise from this source), that this results in 450 millions Euros health external costs + 700 millions Euros external costs due to price loss of houses.

In Belgium *(study done by the Brussels regional environment agency)* it was estimated that almost a third of the city's million inhabitants are exposed to noise levels above WHO recommended levels every night. Around 300,000 people are subjected to noise levels LAmax of 45 dB or more between 11pm and 7am around Zaventem airport.

In 2002 the European Commission promulgated the noise directive (END – 2002/49/EC) having as main goal to determine environmental noise exposure, to inform public on environmental noise and its effects, to adopt "Actions Plans" for preventing and reducing noise when necessary (effects on health) and preserve environmental sound quality when satisfactory for developing a long-term EU strategy.

This legal instrument sets deadlines for its compliance to MS. In 2005 each MS had to identify the national competent authorities and bodies, and establish limit values by source. By 2007 they will have to have strategic noise maps for very large infrastructures (roads with more than 6 million vehicles per year, railways with more than 60 000 trains passages per year and airports more than 50 000 movements per year) and cities with more than 250 000 inhabitants.

By 2008 local and regional action plans will have to be produced to achieve the limit values the MS established, by 2010 a list of large infrastructures should be produced and in 2012 strategic noise maps for those large infrastructures produced.

In summary, at present, only few Member States have data available, but in 2007 all 25 EC MS should have data in L_{night} and L_{den}.

General discussion

The following key issues were discussed based on the presentations.

- Which health measures should be used?
- Who should define the severity weights?
    - WHO?
    - Countries?
    - Expert groups?

- Should the definition of health outcomes be fixed at national or international level?
- How to consider other outcomes (like economic deprivation)?

A vivid discussion took place on which health outcomes to consider, concentrating mainly on annoyance. Annoyance is a very important effect of noise but, it is not a disease. Some participants expressed concern on having it as a health effect, they were arguing that it would create a precedent. All the pollutants annoy people. On the other hand annoyance is a clear manifestation of stress and is the most studied noise effect. Not considering annoyance in a GBD calculation would be refuting a large part of the research made until now. In addition some countries, including the Netherlands, have already considered it in their national calculations. How to consider sleep disturbance was also discussed in detail. Should it be replaced by noise-induced insomnia?

The group has agreed that, for the time being, the document to be produced only cover the European Region and North America, provided that the existing studies were performed there and some data exposure is available. The other Regions will be able to use it, if they wish, and an update should be made when new data is available. The final document should be prepared in a way for Member states to use as a tool for addressing their priorities (providing if possible a calculation sheet in Excel).

Annex 1

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