WORLD HEALTH ORGANIZATION
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Report on the third meeting on night noise guidelines

Lisbon, Portugal, 26–28 April 2005

WHO European Centre for Environment and Health, Bonn Office

ABSTRACT

On the 26th, 27th and 28thof April 2005 the Night Noise Guidelines project's third meeting was held in Lisbon. This meeting reviewed the final version of the background papers and planned future work.

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Background

In June 2004, the WHO European Centre for Environment and Health, Bonn Office, and 17 partners began to implement a project, co-financed by the European Commission, to develop night time noise guidelines (NNGL). For more information on the project please consult http://www.euro.who.int/Noise/activities/20040721_1.

WHO convened the first project meeting in Bonn on 7 and 8 June 2004. 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 aspects and finance.

On 6 and 7 of December 2004 the project's second meeting was held in Geneva with the support of the Swiss Agency for the Environment, Forests and Landscape (SAEFL). Technical discussions took place on central issues like exposure assessment, metrics, health effects, guideline set-up. The partners presented the first drafts of their papers for the different themes and detailed discussion took place for each one of them.

On 26, 27 and 28 April 2005 the **project's third meeting** was held in Lisbon on the premises of the Portuguese General Directorate of Health (DGS). This meeting reviewed and discussed the final version of the background papers and the way forward.

In addition a discussion took place during this meeting on the "*Aircraft noise and health*" document that WHO is producing. The experts were consulted on the document's scientific background, whether its interpretation of the science was correct, the rationale leading to the recommendations and the clarity of presentation for non-scientific audience. The minutes of this discussion are in Annex 1.

Summary of the meeting

Dr Francisco Jorge, Deputy Director General of DGS opened the meeting. He welcomed the participants to the Directorate and Lisbon and wished the participants a successful meeting.

Mr Xavier Bonnefoy summarized the project development thus far, and presented future plans. The project is planned to end in June 2006. At this stage the exposure and metrics are the weak parts, group one has sent a paper but it is rather incomplete.

Presentations

Mr Van den Berg – methodological aspects

The following procedure could be envisaged to derive the guideline values:

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

4. ranking of guideline values.

This procedure was already used in other guideline documents, but for noise the steps had to be more explicitly formalised because sound was an essential part of the environment, which made the use of a no-effect level (NOEL) not useful. A risk-based approach and/or the use of No Observed Adverse Effect Level (NOAEL) would be more appropriate.

A case study of the night regulations in Amsterdam airport was presented. In 1994 a legal requirement of LAeq, 7 hours, inside of 26 dB(A) (approximately Lnight 49 dB(A)) was established. In addition, in 1995 the airport development authorities had to create the necessary conditions for not disturbing the sleep of more than 39 000 people. For achieving these two goals, existing night flights restrictions were reinforced. Afterwards, a study on the health effects of sleep disturbance was carried out. This study shown that in an area of 55x55 km around the airport there were 130 000 people whose sleep was seriously disturbed by noise, therefore several measures were studied to reduce this number: a night quota, a quieter fleet, quiet approach procedures, land use planning, insulation and public awareness campaigns. If these measures were applied, the number of people with sleep disturbance would be reduced by 18% and the airport turnover reduced by 1%.

In this case study, the threshold values were considered very important for assessing the effects and defining the areas of interest, and the dose-effect relationships important for estimating the impact. The DALY methodology was also considered very useful for proving the case.

Discussion

A wide discussion ensued, on general points to be considered in the guidelines' final document.

Regarding the metrics, at least for aircraft, the group stressed that a guideline value expressed in LAmax will have to be complementary to the Lnight! Even a very low number of flights during the night can disturb the sleep of a large number of people. The number of events is just as important as the level of the events. This is important especially for consideration of what constitutes awakenings. Trains, during the night period are as non-continuous as aircraft and the number of events should also be taken into account.

The guidelines document should also have an educative role – what are the effects, how can they be estimated, what can the decision makers do – these would be very valuable elements. Even if the group concentrated on the ideal situation in terms of noise levels, simply ignoring the political scene will not have a positive result. Simply providing a number was politically naïve and the consequence might be that the guidelines would never be put into place. A responsible analysis of feasibility would avoid extreme criticism and a rejection from Member States. The DALY approach would be important for this specific point; the politicians would be able to make comparisons between pollutants and decide on which measures to implement first.

Even with no consensus on how to deal with this point, the group agreed that, whenever possible, the necessary measures to implement the suggested guideline values should be described.

Professor Peter Lercher – Noise management philosophies

The Alpine valley case study was presented in detail. The measures were performed approximately 1000 metres from the highway, 800 metres from the main road and 400 metres

from the train track. Measures were made every six to eight minutes. Different indicators were used and the results differed considerably.

Professor Lercher proposed a meeting in September with the experts from group 1 to finalize the chapter on metrics and exposure. This meeting would discuss how to consider quiet areas, and how to measure the different sources and combined sources. At this stage it was predicted that Lnight would be the metric to use but LAmax and the number of events would also have to be considered. The 10 dB of penalty would be also discussed at this meeting.

Discussion

The main questions around this theme were:

- should the guidelines have source specific indicators?
- should only the acoustical side be considered or also the time of the night (with short LAeq and night distribution)?

New data from trains had shown differences with data from motorways – one train event did not have the same distribution as a truck passing by for example.

It went without saying that the indicators should be health oriented – the LAeq was it not a good descriptor for health effects, events were better descriptors. LAmax and number of events should, when possible, be described, although for road traffic noise it was almost impossible to count the number of events!

A consultation of the decision makers had taken place in Canada; they had said that they wanted few metrics and ease of communication – Lnight and Laeq. The night events were also considered important to consider, particularly in the shoulder hours.

Given the difficulties in reaching agreement, a small meeting should be organized to discuss and agree on this guidelines chapter. This meeting would discuss which extra descriptors will be used with Lnight and how to deal with the different sources.

Dr. Stylianos Kephalopoulos – uncertainty

Dr Kephalopoulos emphasized the importance of doing a risk assessment for noise, based on existing data. The uncertainty should be dealt with on the exposure side; the health effects should be based on solid evidence and not on uncertainty.

Uncertainty existed mainly on estimating the number of people reporting annoyance and sleep disturbance based on surveys and/or outdoor measures. The guidelines values were important mainly indoors, therefore the aspects of insulation should be considered in the document.

Whenever possible, the policy requirements should be addressed and recommendations made for developing future studies. WHO should recommend that they separate sources and assess the exposure-response relationships. Dr Kephalopoulos suggested that for each kind of health effect one metric should be established.

The guidelines should advise on noise health impact assessment suggesting a harmonization of studies – how to consider the sources, multi-sources, specific groups of population, etc.

The economic aspects of noise impact and reduction should also be included, if possible.

The participants suggested that these points should be discussed in detail at the meeting of group 1.

Dr Gaetano Licitra – exposure data

Dr Licitra suggested that the group should on one hand use the open doors of the END directive to propose a metric that will complete the existing ones, but on the other hand, should, seeing that the first noise maps (20% of the population) will be ready soon, use this data. The future maps would have a lot of information that could help identify the problems and support Member States (MS) to identify the priorities in terms of noise pollution, and thence apply the guidelines.

Discussion

Although the END directive was a crucial tool, and would support the guidelines document, the group would concentrate on what was pertinent in terms of public health and find the best metrics to assess exposure.

Dr Dolenc – normal sleep, insomnia

The aim of Dr Dolenc's contribution was to clarify what could be considered as normal sleep and what was sleep disturbance caused by night-time noise exposure.

Disturbed sleep was an important non-auditory effect of noise, defined as "one of those effects on health and well-being which are caused by exposure to noise, with the exclusion of effects on the hearing organ and the effects which are due to the masking of auditory information" (Stansfeld and Matheson, 2003). Noise was therefore an important environmental factor, which had a huge influence on physical, mental and social well being.

The main effect of noise on sleep was sudden awakening; the repetition of sudden awakenings throughout the night might lead to chronic sleep loss with its usual consequences such as chronic fatigue, sleepiness during daytime, and an overall poor quality of life.

Definitions of environmental sleep disorder and insomnia were provided. The symptoms of insomnia were similar to the ones experienced when sleep was disturbed by noise. The Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) establishes the following diagnostic criteria for Primary Insomnia: a) the predominant complaint is difficulty initiating or maintaining sleep, or nonrestorative sleep, for at least 1 month, b) the sleep disturbance (or associated daytime fatigue) causes clinically significant distress or impairment in social, occupational, or other important areas of functioning, c) the sleep disturbance does not occur exclusively during the course of Narcolepsy, Breathing-Related Sleep Disorder, Circadian Rhythm Sleep Disorder, or a Parasomnia, d) the disturbance does not occur exclusively during the course of another mental disorder (e.g. Major Depressive Disorder, Generalized Anxiety Disorder, a Delirium) and e) the disturbance is not due to the direct physiological effects of a substance (e.g. a drug of abuse, a medication) or a general medical condition.

Excessive daytime sleepiness was a consequence of disturbed night sleep and could be objectively assessed providing an objective quantification of "sleepiness". There were significant effects of noise-induced sleep disturbance. A suitable noise descriptor should be used, with

maximum noise levels and a maximum number of noise events. Changes of sleep quality and quantity appeared at levels above 35 dBA.

The American Sleep Disorders Association (ASDA) had devised a scoring system, taking sequences of 3–15 seconds into account for transient arousals which were not transferred to macroscopic behavioural awakening. An arousal index providing the arousal density (events/hour of sleep) had been taken as a measure of the degree of severity. 10–20 arousals/hour were considered normal in healthy adults. However, the use of EEG arousals with the ADSA definition provided insufficient explanation of daytime sleepiness (Pitson and Stradling 1998, Ayas et al., 2001) unless they were accompanied by vegetative arousals.

Different vigilance level assessment in various functional systems were important. Koella (1988) had proposed investigations of vegetative, motoric, and sensoric functions independently of each other. One of the possible factors indicating disturbed sleep was a vegetative arousal index. A vegetative arousal index of more than 30/h was certainly considered as serious, more than 20/h as intermediate and more than 10 as a light form of sleep disorder.

Discussion

Arousals were normal during a healthy sleep. Ten to 20 arousals per hour were considered normal in an adult, but the analysis of arousals was not sufficient. Arousals were activated by the central nervous system and were very important for sleep processing; the problem happened when they were provoked by external factors and abnormally increased. Conscious awakenings were completely different: one or two occurred per night, often followed by 10 to 20 minutes going back to sleep.

There was also a noteworthy age effect related to this “normality”. The best way forward could be to talk about sleep quality and subjective sleep quality. Knowledge of the sleep duration was also important.

There was still a problem among different sleep laboratories because the standards were different. Nowadays technology was easier to transport, therefore the results between field and laboratory studies were merging.

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

The presentation by Professor Alain Muzet was based on a common (draft) paper by Dr Henk Miedema (who was unable to attend the meeting) and Pr Alain Muzet. He made a brief overview of the characteristics of normal sleep and of the mechanisms through which noise affected sleep. Afterwards the findings for EEG response, cardiovascular response, body movement, and conscious awakening were presented.

Noise could 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, total time spent in different sleep stages, and premature final awakening. In addition to these effects, other short-term effects caused by noise included modifications in the autonomic functions (heart rate, blood pressure, vasoconstriction and respiratory rate) and body movements (manifestations of noise-induced arousal during sleep).

Limited arousal reactions without further consequences for sleep could be observed at low noise intensity. Indications of limited arousal were changes in the EEG pattern for a few seconds (disappearance of slow waves or sleep spindles, occurrence of alpha and/or fast EEG waves) together with autonomic signs of activation (increased heart rate for a few seconds, peripheral vasoconstriction). At a higher level, the arousal reaction might be accompanied by sleep stage changes most often associated with EEG and EMG artefacts due to body movements of the sleeper. High arousal could cause a sudden transition from sleep to wake.

The relations between motility and conscious awakening implied that motility is sensitive to noise and had a relatively low threshold, while conscious awakening (the strongest instantaneous interference of noise with sleep) had the highest threshold of the instantaneous effects considered.

In one of the most sophisticated field studies (Passchier-Vermeer et al., (2002)), increased probability of instantaneous motility was found for events with a maximum sound level LAmax ≥ 32 dB(A), while in a meta-analysis, conscious awakening was found for events with LAmax ≥ 42 dB(A) (Passchier-Vermeer, 2003). Above their threshold, these effects were found to increase monotonously as a function of the maximum sound level during a noise event (aircraft noise). It is important to note that in another recent sophisticated field study (Basner et al., 2004), the threshold found for EEG awakening was LAmax = 35 dB(A), i.e. only a little higher than the 32 dB(A) found for noise-induced awakenings. This strengthened the evidence that noise starts to induce arousals at LAmax values in the range 30–35 (A).

When deriving a health based limit the dose-dependent effects of a single noise event needed to be considered. With respect to the dose-dependent effects of a single event, adverse effects could be distinguished from effects that by themselves did not need to be adverse but could contribute to an adverse state. According to this, it was proposed to classify conscious awakenings by noise as an adverse effect during sleep. Conscious awakenings had been estimated to occur at a baseline rate of 1.8 awakenings per night, so that an additional noise-induced awakening meant on average a substantial increment in conscious awakening. Since in general falling asleep after conscious awakening took some time, and this latency was longer after noise-induced conscious awakening that would often also induce an emotional reaction (anger, fear), it would also reduce the time asleep and might affect mood and functioning next day. LAmax = 42 dB(A) was proposed as the currently best estimate of the threshold for conscious awakening by transportation noise. This would mean that the No Observed Adverse Effect Level (NOAELAmax) for transportation noise events was at most 42 dB(A).

The most sensitive instantaneous effect that had been studied extensively in field studies was motility. A single interval with (onset of) noise induced motility by itself could not be considered to be adverse. However, noise induced motility was a sign of arousal, and frequent micro-arousal and accompanying sleep fragmentation could affect mood and functioning next day and lead to a lower rating of the sleep quality. Therefore, motility was relevant for adverse health effects, but more than a few intervals with noise induced motility were needed for inducing such effects. Although additional, more sophisticated analyses could be performed to refine this estimate. LAmax = 32 dB(A) was proposed as the currently best estimate of the threshold for motility induced by transportation noise. It was important to note that the above given NOEL LAmax ≤ 32 dB(A) and NOAEL LAmax ≤ 42 dB(A) were indoor levels, in the sleeping room.

The following groups might be hypothesized to be more vulnerable to noise during sleep: old people, ill people, people with chronic insomnia, shift workers and people resting during

daytime, people with tendency to depression, light sleepers, pregnant women, and people with high anxiety and high stress levels. Furthermore, children needed special attention because of their relatively high exposure during sleep, and because they were in a crucial phase for neurocognitive development during which having an undisturbed sleep might be particularly important.

Discussion

The German sleep association had claimed that even when a person did not recall being awake there were possible adverse consequences. Conscious awakenings were the extreme event, for example sleep apnoea patients did not complain about their sleep and their sleep was not efficient. The noise level necessary for provoking an awakening also depended on the sleep stage a person was in.

What we were missing as well was knowledge on hormone secretion during sleep. There was still a big gap on knowledge on this matter – although some evidence existed for road traffic.

Lnight of 42 dB(A) and LAmax ≤ 32 dB(A) indoor were the NOAEL (for "normal and healthy" sleepers. Can also a number of events be associated with these figures?

Dr Sona Nevismalova – Long term noise-induced health risk mediated particularly by sleep disturbances

Insufficient nocturnal sleep and sleep restriction gave rise to behavioural and cognitive impairment, even neurological and other medical problems, and reflected negatively on the affected subjects' quality of life.

Dr Nevismalova had updated her paper since the second meeting and proposed some noise levels for avoiding sleep disturbance by noise.

Critical health effects could appear when maximum average nocturnal energy level inside bedrooms exceeded Leq 30 dB(A) and outside bedrooms Leq 45 dB(A) and in the presence of a limited number of events per hour with an energy exceeding the baseline level of LA max. 45 dB(A) level (inside bedrooms) and/or 60 dB(A) outside bedrooms. The peak level of 60 dB(A) inside bedrooms and/or 75 dB(A) outside bedrooms should never be exceeded in any case.

Apart from those for the healthy population, norms should be devised and strictly adhered to in hospitals, particularly in intensive care units

Professor Stephen Stansfeld, Dr Michal Skalski – night noise and mental health

Professor Stansfeld completed and updated the background paper that he and Dr Skalski had produced for the second meeting. Noise exposure at night might be more disturbing than daytime noise because it interfered with rest and sleep at a time when people wanted to relax. It seemed plausible that night time noise might have a particular effect on mental health. However, there was little direct research on night time noise and mental health and it was first necessary to consider the evidence for environmental noise and mental health in general.

At the present time, exposure-effect associations had not been established between parameters of sleep disturbance (number of behavioural awakenings, body movements or EEG awakenings)

and the onset of depressive and anxiety disorders although there was some evidence that insomnia was a risk factor for developing depression (Riemann et al., 2001; Roberts et al., 2002). A number of longitudinal prospective studies in different age groups had found associations between self reports of insomnia and the subsequent onset of psychiatric disorder, in particular major depression.

The evidence was not strong for the association between noise exposure and mental ill-health. The existing evidence suggested that noise exposure might be responsible for psychological symptoms above 70 dBA Leq. Almost all studies had only examined the effects of day time noise on mental health, but it was possible that night time noise, during sleep time, might have effects on mental health at lower levels than day time noise.

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

Discussion

A person's house was a place where one should feel secure from outside aggressors. Noise had an intrusive character and might provoke anxiety. Being able to control it was of crucial importance in terms of mental health effects. The level of anxiety that it could provoke depended on the individual coping with the noise.

There was a genuine lack of evidence. Insomnia predicted all kind of health effects therefore it was very difficult to use it as a proxy. There was not enough knowledge of what happened beforehand (ie before depression or insomnia).

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

Dr Babisch, had also updated his background paper for this meeting. He presented the comprehensive meta-analysis carried out, and added guideline values for the CVD effects.

Sufficient evidence existed for an association between community noise and ischaemic heart diseases; limited/sufficient evidence existed for an association between community noise and hypertension. Most information came from road traffic noise studies but there was normally little information regarding night noise in particular. But night time values could be extrapolated from day time results.

Below 60 dB(A) for Lday there was no noticeable increase in MI risk to be detected. Therefore for the time-being, Lday = 60 dB(A) could be set as the NOAEL ("no observed adverse effect level") for road traffic noise and myocardial infarction (Babisch, 2002). For noise levels greater than 60 dB(A), the MI risk increased continuously, and was greater than 1.2 for noise levels of 70 dB(A).

Discussion

Normally CVD effects manifested themselves after 10 years living in a noisy area.

There was a question whether the results from daytime could be translated to night time and if a person reacted the same way while sleeping: the answer was yes. In the Spandau study the results were not so different.

However, when sleeping, a person reacted to lower levels, therefore the 10 dB from the Lnight was established to consider it, although the sleep labs considered 10 to 15 dB difference. Therewas also literature showing that even if the noise was 15 dB lower, the person reacted twice as much! When a person was asleep he or she did not cope with the noise.

The aspect of measuring at the front of the house, and having the bedrooms in the back of the dwelling was raised. If we were analysing day time effects the fact that people might sleep in the back had to be considered. Dr Babisch clarified that these studies have a conservative approach and consider only the lower exposure side of the dwellings with control groups that didn't have noise during the day or during the night, so what could happen was a underestimate,not an overestimate.

Significant results for hypertension and military aircraft were found in Japanese and German (Ising) studies, but, for example, the German study did not include any night flights. Maybe it would be possible to find if night flights could be extrapolated from the Okinawa study. This would be important to help establish a number of events.

Professor Staffan Hygge – Night noise and cognitive impairment

The relationships between night-time levels and cognitive performance mediated by reduced sleep quality were analyzed. Professor Hygge concentrated on night time levels, the differences between children and adults and the role of restoration. The results of the Munich study and RANCH (by Professor Stansfeld) were presented.

On the Munich study there were errors in reading that were significantly reduced after the airport closure. On the other hand, the errors increased in the school close to the new airport. There did not seem to be any effect of night time noise exposure on children's self reported sleep quality, in spite of a substantial average shift in combined day-night noise level in the exposed group at the old and new airports.

Unfortunately there was no information on night noise levels. It was not known exactly how much aircraft night noise there was at the two airports, only that the airport operated further into the night. Considering the sleeping hours for children aged 9–12 years, there should have been some early night noise level difference between groups. However this did not show up as loss of sleep quality, neither for the children, nor for their parents.

The RANCH study focused on noise at schools during the day, and relationships were found with reading, episodic memory and increased noise.

In the United Kingdom, 842 children were surveyed from 23:00 to 7:00 with a noise level of 53 dB(A) in day, 42.9 dB(A) night.Night-time aircraft exposure showed no additional impact on reading and recognition memory beyond the effects of daytime noise exposure.

It had to be strongly acknowledged, however, that neither the Munich nor the RANCH studies were designed to assess the impact of night noise on cognitive functions. There was only a

survey question on the self assessed sleep quality, and it was recognized that this was not the best way to assess sleep quality.

Discussion

Neither of the studies that were presented included information on how the children slept, therefore it was difficult to derive any conclusions. The results were not enough to draw conclusions on effects.

It was also known that people living close to an airport quite often misevaluated their sleep quality.

Children did not wake up as easily as adults, they seemed to have a protective "system" that protected their sleep, but there was a strong reactivity to noise and there were impacts on the autonomic functions.

Dr Svenaza Yovanovic – Children accidents

From the existing sleep literature it could be concluded that children with disturbed sleep present ed cognitive dysfunction and behavioural disturbances, abnormal growth hormone release, increase of diastolic blood pressure, increased risk of accidents and use of sleeping pills.

According to a study (Menchini et al., 1985) childhood accidents occured 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 were the most common types of injuries and also the most likely linked to sleep disturbance in young children. Results suggested that children with more frequent injuries had significantly more sleep problems, and that there was an increased prevalence of sleep disturbances in preschoolers with increased injury rates.

Sleep disorders were more often mentioned by children than by their parents, likewise sleep disturbances by light and noise!

Results of a study on sleep disturbance and injury risk in young children showed that inadequate sleep duration and lack of daytime naps were transient exposures that might 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.

Daytime sleepiness in children was 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).

Duration of sleep required to minimize injury risk in childhood was not easy to quantify, because normative values for sleep duration varied across cultures. In a study with 40 000 children (11 to 16 year old) from 11 countries, significant differences of average sleeping times between countries were found. Israeli children were the ones that slept the least, and Swiss slept the longest (Tynjala et al., 1993). As an example, American infants in the 1990s slept 13 hours per day at the age of 3 months, and Dutch babies slept 15 hours per day.

Analyzing school attendance, the data showed that accidents took place at school (25.6%) and at home (22.0%), and there was a statistically highly significant greater total accident rate in boys

than in girls. The most frequent injuries happening at school were fractures and dislocation of joints, head injuries being the most common among school injuries compared with spare-time injuries. Most injuries occurred when children were in sport areas and 25% of all injuries were caused by other pupils through intentional violence.

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

A very interesting analysis was carried by Leger et al., showing the costs of road, work, home and public accidents and the estimation of the costs attributed to sleepiness – normally in all cases the attributed cost was very high (e.g. motor vehicle accidents total costs were 70.2 MRD$ being the costs attributed to sleepiness 41.5% of this amount).

Discussion

Some people were sleepy because they decided not to sleep. Could a differentiation be made between the ones that didn't want to sleep and the ones that were prevented from sleeping? This was very difficult to differentiate, but we could have an attributable fraction of people being disturbed by noise and then extrapolate on the percentage of accidents caused by it.

Dr Christian Maschke – Effects of noise on the immune system

The presentation of Dr Maschke concentrated on hormone secretion and its health signification. It is not a simple topic and the mechanisms had to be explained in detail.

In the last 20 years psycho-neuro-immunology had developed into an independent discipline. Psycho-neuro-immunology dealt with the interactions between the nervous, hormone, and immune systems. Stress, behaviour, condition and sleep were the focus of research. Psycho-neuro-immunology had expanded the knowledge of the hormonal system considerably. Until now, noise effect research had not kept pace with this development.

The hormonal system was active in every single cell of a human being. The hormonal system contained the endocrine part that consisted in secretion of hormones from special glands, each with a special function. The endocrine part included the hypophysis as the control gland of the endocrine system, controlled by the hypothalamus by means of inhibiting or stimulating hormones and the thyroid, adrenal cortex, pancreas, parathyroid, gonads, epiphysis (pineal body) and the thymus, which also maintained the connection to the immune system.

The adrenal medulla also represented an endocrine gland. However, it was controlled by the vegetative nervous system.

The paracrine part of the hormone system consisted of special cells which were distributed throughout the entire body. The hormones which were produced in these cells were described as tissue hormones. While the endocrine system secreted the hormones into the blood, the paracrine hormones were passed on through inter-tissues and brought to the final destination.

Nerve cells were also able to produce hormones (neurohormones and neurocrine part of the hormone system). Neurohormones could be secreted into the blood or taken to the synapse directly.

The immune system was narrowly connected with the hormonal system. Certain hormones stimulated the receptors of the immune system and triggered immunologic effects.

Already from this short description it was obvious that neuro-endocrine activity was much more complicated than had been described by Hans Selye [1936]. Therefore, an isolated view of the so-called stress hormones (catecholamine, cortisol) did not do always justice to neuroendocrine activity.

To conclude, even if information were available on cortisol secretion during a noisy event, it was not an easy task to assess its health significance. The most advanced studies on this field had never considered noise. Extrapolating a NOEL could be done, but its health significance was not possible to quantify at this stage. The existence of hormones by itself is not health significant.

Discussion

Despite limited knowledge in this area, could some of the existing information on noise and hormones be included on the guidelines? It was a difficult question. A normal level of cortisol, per se, did not mean anything, and an abnormal cortisol level meant that there was a deregulation, but the literature did not say anything about its impact on health. There were only two studies on noise and cortisol, more studies were needed! Results from other existing studies were contradictory.

If included on the guidelines this topic needed to be more detailed. The group proposed that should organize a small meeting for this topic exclusively. This meeting should deal with the available knowledge, existing evidence, identify gaps in knowledge and if possible and have a pedagogic character for noise experts and as reference for future studies.

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

Professor Bruni also updated the paper he had prepared for the second meeting. He had been requested to give the assumed criteria and explain in detail the table he had proposed at the Geneva meeting.

For children, the guideline values should be those ensuring a healthy sleep. For the time being, this could be the lowest level of noise for which studies demonstrate a clear and significant disturbance of sleep in children.

The night period, when the noise levels were supposes to be low, was becoming very short (3 to 4 hours). Recently, a traffic analysis in most Italian cities showed that noise limits are exceeded almost every night and, in percentage, more during night-time than during the daytime.

The CAP rate (mostly A1 index) showed a strict relationship between Growth Hormone (GH) secretion and growth velocity. The effects of noise could be to disrupt Slow Wave Sleep microstructure and therefore GH secretion.

Slow Wave Sleep (SWS)and REM sleep have important functions in children's sleep. Having an undisturbed sleep during these stages was related to normal growth and learning. If the noise occured during the 1° cycle of SWS when growth hormone was secreted, it could have more detrimental effects than during other phases, and effects than it would have on adults.

Although it should be taken into account that it was at present not known whether children were possibly more sensitive than adults to night-time noise, it could be deduced that the effects of night-time noise during sleep in adults also applied to children. For the effects for which solid evidence was missing we should use an approximate approach based on daytime findings and based on the precautionary principle.

The metric to be adopted should consider the average background noise level that did not provoke any effect and should allow the evaluation of the number of arousals and awakenings. It was known that adults' physiological responses appeared at an LAeq in the bedroom of approximately 40 dB(A,) and behavioural awakening occured when the bedroom Lmax exceeded 55 dB(A). Since childre'sn autonomous nervous system was more activated by noise (acoustic stimuli of much lesser intensity 10 to 15 dB) when sleeping, it could be assumed that children were more sensitive also to the detrimental effects of noise exposure.

All children (0–12) should be considered at risk, but especial attention should be paid to some specific groups such as low birth weight, small for gestational age babies, preterm infants, learning disorders, behavioural disturbances (i.e. hyperactivity) and sleep disordered children.

Professor Hartmut Ising – Animal Studies

The results of animal experiments, experiments on humans, and epidemiological studies showed consistently that chronic exposure to environmental noise increased the risk of hypertension.

According to a model established by Professor Ising and Dr Kruppa, arousals preceded endocrine reactions and appeared within 1 second after a noise stimulus. Hormones like catecholamines took several minutes, and cortisol about ten minutes to be increased. This led to the conclusion that when noise exposure did not evoke arousals in sleeping persons, would not induce adverse health effects.

On a study with 68 children the excretion of cortisol had been measured in the first and in the second half of the night during a period of 5 years (by their physicians). Night time exposure to road traffic noise had been correlated to an increased cortisol excretion in the first half of the night and this increase was significantly correlated to an increased frequency of physician contacts (reporting bronchitis).

Animal studies had shown that noise increased the calcium and magnesium accumulated on the cells, provoking a premature aging of the heart. Ageing was one of the biggest risk factors for heart attack and this effect of noise should not be underestimated.

Long term exposure of children to the combination of traffic noise and air pollution aggravated respiratory diseases more than exposure to air pollution alone.

Discussion

The type of animals used should be described on the final document, because some types of mice did not absorb magnesium.

How could these results be translated to humans? The experiments described involved chronic noise exposure, which almost never happened in humans. This had to be accurately acknowledged.

Mr Colin Grimwood – Neighbourhood Noise – guidelines

Mr Grimwood's presentation consisted of a series of very pertinent questions about the future guidelines' document.

The first question was about the nature of the noise. Were the guidelines being defined as noise type 'continuous noise', and 'intermittent noise events' (like the existing WHO Guidelines) or by noise source (specific/general)? Transport noise, neighbour noise – noise produced by a person's neighbours (and their pets), neighbourhood noise – all noise produced in the neighbourhood, but not noise from neighbours or noise from transportation (i.e. including entertainment, sport and leisure, industry, commercial premises, construction and demolition, roadworks, farming, agriculture …), or even by effect(s) of noise? (were sleep effects the only critical health effects at night?), or applied to specific environments? (adults/children/pre-school bedrooms? Recommending use of time limits – times when neighbourhood noise could and couldn't be made (or heard) e.g. no lawnmowers before 9am or after 9 pm, no fireworks after midnight)?

Establishing a threshold level for neighbourhood noise was an almost impossible task: should inaudibility be used as the no effect level for night time? Inaudibility was currently used as a guideline for night time entertainment noise in Scotland. At present the WHO 30 dBA guideline value was often cited in legal proceedings as a justification to continue making night time neighbourhood noise. Neighbourhood noise complaints were common at noise levels of 30 dBA.

The other questions addressed and answered:

1. Were existing laboratory and field (transport noise) research findings on dose/response, noise events and motility, habituation, sleep effects, effects of change in noise level, role of acoustic and non acoustic factors applicable to all the different types and sources of neighbourhood noise? Not sure
2. Were there unique factors (acoustic and non-acoustic) applicable to the different types of neighbourhood noise? Yes!
3. Did the following acoustic factors mean that it was not appropriate to derive guideline values for neighbourhood noise?
    - sound pressure level
    - loudness
    - audibility
    - spectral characteristics, low frequency content
    - tonality
    - impulsiveness
    - irregularity
    - intermittency

- unpredictability
- duration
- emergence over background.

4. And these relevant non acoustic factors?
   - time-of-day, season of year
   - type of area
   - attitudes to source
   - information content
   - 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…
5. Did these factors mean that the existing body of noise research was not sufficient to allow specific authoritative guideline values to be derived for individual neighbourhood noise sources? Yes!

   Did these factors mean that it was not appropriate to derive guideline values for neighbourhood noise? Not sure!

   Or

   The use of a Guideline Value might be appropriate but only in circumstances where the acoustic and non acoustic features of the neighbourhood noise were not important?

   Or

   That the general research findings on sleep effects and noise were considered relevant to neighbourhood noise irrespective of the acoustic and non acoustic factors?

   Or

   That the general research findings on sleep effects and noise weere considered relevant where the type of neighbourhood noise had similar features to transport noise (i.e. continuous or consisting of a number of intermittent but similar events)?
6. What should WHO NNG say about neighbourhood noise?
   - That the no effect level for many types of neighbourhood noise might be inaudibility?
   - That the no adverse effect level for some types of neighbourhood noise might be the same as that derived from transport noise studies particularly where the neighbourhood noise was continuous or consisted of a number of intermittent but similar events?

- That the no adverse effect level for many types of neighbourhood noise was probably lower than that derived from transport noise studies because of the special features of this type of noise?

This very provocative presentation caused a lively discussion; most of the questions were also addressed at the plenary section and originated conclusions.

Discussion

Audibility could not be the guideline value, this would cause very strong reactions and it would be a value impossible to achieve. If WHO proposed this value it could originate adverse effects if taken out of context and thus put at risk the credibility of the group.

Neighbour and neighbourhood noise would be a separate chapter of the guidelines, they wee clearly different from transport sources. This chapter could also have a pedagogic character to providence guidance for future studies; studies were needed on this field.

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

Dr Mueller Wenk also updated his paper according to discussions at the second meeting.

Dr Mueller Wenk considered sleep disturbance caused by a long term exposure to nocturnal road noise as a disease itself. He based this statement on the judgements of patients having Obstructive Sleep Apnoea Syndrome as well as on noise-related sleep disturbance.

Under the conditions of a highly developed and densely populated country like Switzerland, the night time noise due to road traffic caused approximately 50 000 cases of sleep disturbance per million of persons. With a disability weight of 0.055, this resulted in a burden of disease that was at least as important as the burden of disease due to premature deaths caused by road accidents.

Even if calculations were made on the basis of recent studies considered to underestimate the road noise exposure of the population (ARE 2004), as well as the night-time noise sensitivity of the population (DLR study Samel 2004), it could be shown that the corresponding ‘low’ value of the burden of disease due to road-noise-related sleep disturbance was of a magnitude that justified and required public action.

Discussion

Was the method used for Switzerland also valid for the other countries? WHO had a parallel working group for estimating the burden of disease of noise and the night time noise results would be included on the guidelines.

Conclusions

1. The guidelines would be established for, mainly, sleep protection (objective and subjective (self reporting) sleep quality), and only a small part of the document would be dedicated to annoyance for people being awake during the night.

2. The possible measures that Member States should undertake to implement the guideline values should be described when possible.
3. The final document should include success stories and noise reduction case studies.
4. The message had to be clear and to be understandable by most people.
5. Times of night; number of events; and duration of the events should be considered, but the metrics should be kept simple. Lnight and LAmax per source would be used.
6. A small meeting could be organized on exposure and metrics (probably in September 2005 in Vienna).
7. Sleep was measured objectively and subjectively – The final document would describe sleep quality and insomnia.
8. There was unanimous agreement that disturbed sleep had serious health effects – solid evidence existed in sleep medicine, the insomnia model would be used as a proxy and its causes and effects described on the final document.
9. The analysis of the evidence suggested that Lnight outdoor>42 dB(A) induced sleep disturbances.
10. The NOAEL (non observed adverse effect level) (during sleep) was Lnight 42 dB(A) outdoors.
11. A positive attitude towards noise could minimize its effects.
12. Standards should be devised and strictly adhered to in hospitals, particularly in intensive care units.
13. The autonomic nervous system was more easily activated in children than in adults; there seamed to exist a "protective" mechanism that kept them sleeping – sleeping was crucial.
14. Studies carried out in the United States would be included – Dr Michaud would provide the pertinent ones.
15. Noise did not seem to have a direct influence on mental health, maybe sleep mediated, but there were not enough studies – the evidence simply did not exist!
16. Dose response relationships between military aircraft noise and 'mental instability' and 'depressiveness', were found but only for high levels >70 Ldn.
17. Perceived "controllability" of noise (possibility of switching it off) was of crucial importance.
18. The NOAEL for Myocardial Infarction was Lday = 60–65 dB outdoors and Lnight outdoors = 50 – 55 dB for road traffic.
19. It was not shown that the recorded 24 hours noise levels in the Munich study impaired self reported sleep quality, neither for the children, nor for their parents but the study was not developed to analyze sleep disturbance.
20. Chronic exposure to environmental noise increased the risk of hypertension.
21. Animal studies showed that excessive exposure to noise caused ageing of the heart – the main risk for myocardial infarction.
22. The guidelines would include transportation noise defined by source. In addition continuous noise', and 'intermittent noise events' would be described.

23. The "deriving guidelines" chapter on the final document would summarize the background papers to ensure an easily understandable structure (per source and per effect).

24. A first draft of the chapter "deriving guidelines" should be produced by Mr Van den Berg, proposing an answer to the questions around it and the expert group would then comment and improve it!

25. A chapter should be devoted to (neighbour) neighbourhood noise – its contents would be "different" from the other sources – No specific guidelines values would be developed for neighbourhood (and neighbour) noise, only when possible they would be derived from transportation noise studies – with special restrictions.

26. A chapter should be developed on the burden of disease of night noise supported by the work WHO is developing in parallel.

27. Whenever possible, the health effects of noise exposure to levels above proposed guidelines should be described and quantified.

28. A smaller meeting on hormone secretion and their significance could be organized.

29. Developing a table like the following was considered useful (if feasible):

Effect	**Lnight outdoor**		**Number of events with duration**	**Lamax outdoor Or difference between background level**	**Duration of exposure**
Sleep disturbance Children	Road	42 dB(A)	Arousals /CAP rate – which level?		
	Rail				
	Air				
	Combined				
Sleep disturbance Adults	Road				
	Rail				
	Air				
	Combined				
Cardiovascular diseases – Ischemic heart disease – hypertension	Road	50 dB			10 years
	Rail				
	Air				
	Combined				
Other					

Follow up – Timetable

According to the contract with the European Commission, the project should end in June 2006. To finalize within this period, two smaller meetings could be organized in

- Sept 2005 on exposure, metrics – in Vienna
- October 2005 – health significance of hormone secretion

The partners should finalize their papers as soon as possible (or send their paper to the secretariat if not yet presented). The final document would summarize them according to the table of contents presented in annex 2 (still not agreed upon).

A professional senior editor would be hired to compile and summarize the background documents. He/she would produce a first draft to be revised by this group. After corrections, an external group of experts would also be requested to review the document and the results would be discussed at a final meeting.

In May 2006 the project final meeting with the participation of WHO/European Commission/C Member States would be organized in Bonn. This was envisaged to be a technical and political meeting, one day for exclusively technical aspects and one or two days for the political part.

Annex 1

DISCUSSION ON THE AIRCRAFT NOISE AND HEALTH DOCUMENT

Zoning aspects and their consideration on the document were discussed at the beginning of the discussion – the group suggested discussing it in the document– was it efficient? Why did it not work? Should the noise be distributed between the different zones around the airport or concentrated only in one?

The group suggested including something on **landing charges** – at present in several airports, fines are levied by the airport managers from noisy aircraft. This aspect of "**economic instruments**" should be considered in the brochure – maybe this money should be used by the community!

The issue of evening and early morning hours was raised – something should be added.

The group was asked to discuss the suggested comments one by one; the following text summarizes the discussion:

- Consider vibrations
  YES
- Low birth weight of children from mothers exposed to aircraft noise
  NO – very controversial
- HYENA project
  NO – only published studies should be included
- Directive 2002/49/EC
  YES – Annex 1
- US field studies at least with respect to awakenings
  YES – if they fulfil the requirements of the WHO document *Evaluation and use of epidemiological evidence for environmental health risk assessment*.
- Section on noise emissions of aircraft, the document lacks any description of the type of air noise, frequency distribution, time history, discontinuity, rapidity, propagation. Add short explanation on the descriptors, (dB(A)? LAmax?)
  YES –a box would be added on this or a short mention would be included in the text– Gaetano Licitra would help writing it
- Phonic epuration and poverty: were airports going to generate new ghettos because only the rich can escape this noisy area,**?**
  Yes – the RIVM had recently produced a report for road traffic – and also a German study demonstrated a high correlation between socio – economic status and noise. These results would be included, with a caveat to clarify that the conclusion was extrapolated from road traffic noise.
- WHO should qualify the statements about CVD and noise by at least providing athe duration of exposure. Perhaps this would be an appropriate section to define what the

WHO is using as a definition of hypertension, or what these studies have used
Yes. This will **be clarified. CVD is chronic – more than 10 years**

- Air transport helps less in industrialized countries affected by disasters and contributes to rapid transport of sick people towards tertiary care centers,
  They benefit in a very different way
- Regarding sleep disturbance and insomnia: this part was very unclear, definitions lacking
  The definition of environmental insomnia would be included – some word about the meaning (socio-acoustical aspect) of the noise might be added
- The paragraph "Sources of noise" was very technical and used a lot of aero-engineering words which the reader cannot be expected to know like: airframe, passby ratio engines, thrust settings, turbo-props. The style of writing suddenly changed from very general to very technical
  Editorial details – the style of the document was to be uniform
- Discuss the role and possible benefit of health impact asssessments (HIA)
  NO – not considered useful
- The noise reduction measures section needed a final linking containing the following points:
  Whilst these noise reduction measures are known to reduce noise, there is less evidence to suggest that they in turn improve health,
  Preliminary evidence from a few "intervention studies" have suggested benefits for community health when noise is reduced.
  (Maybe consider raising the precautionary principle here?)
  A discussion took place about annoyance reduction and complaints reduction and their significance – an increase of the number of flights increase annoyance. No consensus was achieved. Martin van den Berg and Dr Alain Muzet offered to send some documents to support the different points of view.
- "Annoyance is frequent....however it is clearly a manifestation of stress and has many associated health effects." Was the WHO making a distinction between annoyance and high annoyance? If not, any degree of annoyance might be interpreted to have adverse effects on quality of life. Also, it might only be that when annoyance was "high" that it becomes a health concern. Likewise, it might be important to indicate that even high annoyance must be chronic for it to become a potential health hazard. It would be informative to also include a WHO definition of "chronic" ,
  Yes, **the wording would be fine tuned – chronic annoyance should be used**
- Page d16, column 1 second paragraph: once we change deprivation by disturbance, does hypertension remain questionable?
  No – disturbance can be used and the results will still be valid
- Using insomnia as a proxy to assess noise effects on sleep could be flawed in as much as it would not account for brief arousals that do not cause awakenings, changes in sleep stage that do not cause awakenings, increased awakenings that do not result in difficulties returning to sleep, premature awakenings towards the end of the sleep period time, etc.
  This result from another expert group discussion that discussed sleep in detail, the experts agreed that ????
- There was little evidence that the full 'flight or fight response', as described in this section, is caused by aircraft noise during sleep,
  The document wanted to pass strong message, but this mechanism is very complex.

The fact that the coping and un-coping mechanisms were activated or not is of considerable importance. When a person was sleeping, this flight or response did not occur. Dr Michaud volunteered to rewrite it

- Describe the habituation to sleep with noise but the lack of habituation of the autonomic responses
  Yes, this would be added
- It may be informative to indicate that in the van Kempen et al., 2002 review the authors were unable to identify a threshold above which one's RR increased by 1.26 for each 5dBA increase,
  There was not enough data to describe the threshold – the author himself could not. A disclaimer should be added
- Was there any evidence that environmental noise exposure adversely affected hearing in children? Such a statement required a reference,
  For military aircraft yes (in Quebec)
- One could not say that aircraft noise caused disturbed sleep and therefore, health problems in children – where is the evidence?
  Children were not, in fact, easily awakened. but their nervous system reacted more easily (paper of Dr Bruni)
- Landing and taking off – a discussion was held on which is noisier. A comment was made that the brochure concentrated more on landing, but take off was also very important. This depended on the place where it was measured,
  No consensus was achieved; Martin van den Berg and Gaetano Licitra would send some documents to support the different points of view.

Recommendations

Rec 1 – The time of the curfew should not be given. It should be at least 8 hours curfew or 8 and a half hours curfew.

Rec2 – The concept of zoning should be added here. Economic instruments / internalization of costs (such as landing charges) should also be mentioned here.

Rec 3 – the title should be changed – changed from the 1st sentence on – it's completely different from its text
"Building residential … should be discouraged by all means" instead of " should be prohibited"

Annex 2

PROPOSED TABLE OF CONTENTS OF THE FINAL DOCUMENT

CHAPTER VI. GUIDELINES AND RECOMMENDATIONS

1. NO(A)ELs
2. Dealing with situations exceeding the NOAEL's
3. Neighbourhood noise and noise from neighbours
4. Protection measures & control
5. Recommendations
6. References

Annexes

Annex 3

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