THE HANDBOOK OF THE EFFECTS OF ENVIRONMENTAL NOISE ON HEALTH

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The handbook of the effects of environmental noise on health

- A publication of the Finnish Ministry of the Environment

  http://www.who.int/docstore/peh/noise/guidelines2.html

- Deals with noise in accordance with the WHO recommendation of the classification of diseases, impairments and disabilities due to various external and internal causes

- Stresses the various noise effects

- Helps the environmental authorities in their work
Contents

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2. Sound and noise
3. Annoyance
4. Physiological effects
5. Noise-induced hearing loss
6. Long-term effects
7. Noise effects in different population groups
8. Research of noise effect
9. Noise abatement
10. Conclusions

Appendix: WHO guideline values for environmental noise
Noise

• unwanted sound that human beings consider unpleasant or disturbing

or

• in some other way is harmful to the human health or well-being
Factors relating to effects of noise
Health effects of environmental noise according to the terminology of ICIDH* (WHO)

<table>
<thead>
<tr>
<th>External exposure or/and internal cause</th>
<th>Examples (noise effects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disease</td>
<td>- organ or cellular lesion - inner ear lesions</td>
</tr>
<tr>
<td>Impairment</td>
<td>- measurable change of function - blood pressure</td>
</tr>
<tr>
<td>Disability</td>
<td>- experienced functional effect - annoyance</td>
</tr>
<tr>
<td>Handicap</td>
<td>- handicap for an individual - morbidity, working ability</td>
</tr>
<tr>
<td></td>
<td>- handicap for the society - need of health services</td>
</tr>
</tbody>
</table>

* ICIDH = International Classification of Functioning, Disability and Health
Noise effects

- Sleep disturbance
- Annoyance
- Impaired speech communication
- Impaired cognitive performance
- Increases risk of cardiovascular disease
- Hearing impairment

NOISE
Annoyance

• immediate **behavioural** noise effects aspects, like disturbance and interfering with intended activities

  *and*

• **evaluative** aspects like “nuisance”, “disturbance”, “unpleasantness”, and “getting on one's nerves”
Relationship between the percentage of highly annoyed and the sound level of traffic noise ($L_{DN}$) (Fidell et al. 1991)
Annoyance caused by aircraft, road traffic and railway noise

Relationship between the percentage of highly annoyed persons and $L_{dn}$ for air, road and railway traffic noise (Passchier-Vermeer W, Passchier W 2000)
## Noise effects on sleep and relaxation

<table>
<thead>
<tr>
<th>Primary effects</th>
<th>Secondary/after effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>- difficulties to fall asleep</td>
<td>- reduced perceived sleep quality</td>
</tr>
<tr>
<td>- alterations of sleep stages or depth</td>
<td>- increased fatigue</td>
</tr>
<tr>
<td>- awakenings</td>
<td>- depressed mood or well-being</td>
</tr>
<tr>
<td>- increase in body movements, heart rate and blood pressure</td>
<td>- decreased performance</td>
</tr>
</tbody>
</table>
The relation between sleep and health

In the figure the relations with sufficient evidence are indicated with solid lines, while relations for which limited evidence exists are indicated with interrupted lines. Feedback connections are in red and double-dotted.

Source: Night noise guidelines for Europe, WHO
Effects of night-time road traffic noise


Swedish soundscape research programme; WHO Night Noise Guidelines for Europe 2009
Effects of road traffic noise at night

Source: WHO Night Noise Guidelines for Europe 2009
Effects of aircraft noise at night

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

Source: WHO Night Noise Guidelines for Europe 2009
## Thresholds for effects of night noise with sufficient evidence

<table>
<thead>
<tr>
<th>Effect</th>
<th>Indicator</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biological effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in cardiovascular activity&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EEG awakening</td>
<td>LA_{\text{max,inside}}</td>
<td>35 dB</td>
</tr>
<tr>
<td>Motility, onset of motility</td>
<td>LA_{\text{max,inside}}</td>
<td>32 dB</td>
</tr>
<tr>
<td>Fragmentation of sleep structure&gt;</td>
<td>LA_{\text{max,inside}}</td>
<td>35 dB</td>
</tr>
<tr>
<td><strong>Sleep quality</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waking up in the night</td>
<td>LA_{\text{max,inside}}</td>
<td>42 dB</td>
</tr>
<tr>
<td>Prolongation sleep latency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep fragmentation, reduced sleeping time&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased average motility</td>
<td>L_{\text{night,outside}}</td>
<td>42 dB</td>
</tr>
<tr>
<td><strong>Well-being</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-reported sleep disturbance&gt;</td>
<td>L_{\text{night,outside}}</td>
<td>42 dB</td>
</tr>
<tr>
<td>Use of somnifacient drugs and sedatives&gt;</td>
<td>L_{\text{night,outside}}</td>
<td>40 dB</td>
</tr>
<tr>
<td><strong>Medical conditions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental insomnia</td>
<td>L_{\text{night,outside}}</td>
<td>42 dB</td>
</tr>
</tbody>
</table>

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

**Source:** Dr. Rokho KIM  Night Noise Guidelines for Europe
Impaired speech communication

• Communication disturbances (auditory)
  - noise masking
  - problems in speech discrimination

• Communication disturbances (voice)
  - lesions of the vocal cords (secondary)->
    - hoarseness, voice fatigue
Prevalence of deviations in voice production on different noise levels \textit{(Klingholz et al. 1978)}
Disorders of cognitive performance

- In children chronic aircraft noise exposure has been associated with poorer reading comprehension, limitations in learning-ability and sustained attention.

Weakening of reading comprehension by increasing equivalent continuous sound level of aircraft noise ($L_{Aeq}$, dB) (Stansfeld et al. 2005)
Physiological effects of noise

- Direct reactions to noise are mediated by nervous and/or endocrine transduction to different organs without cortical intermediation.

- Acute noise exposure activates the **autonomic nervous system** and **endocrine system**, which leads to temporary changes such as increased heart rate, vasoconstriction and increased blood pressure.

Transmission paths of direct noise effects (adapted from Ising and Rebentisch 1993)
Noise as stress

Noise activates the **sympathetic-adrenal-medullary (SAM)** axis and the **hypothalamic-pituitary-adrenal (HPA)** axis

- increased heart rate, vasoconstriction and increased blood pressure,
- increases in levels of stress hormones adrenaline, noradrenaline and/or cortisol
The possible relationship between noise, stress and development of diseases

- Noise / Sound
- Physiological responses
- Means of controlling responses
- Chronic stress
- Disease
Hypertension

- Epidemiological studies have suggested a higher risk of hypertension, in subjects who were chronically exposed to high levels of aircraft noise.

- Hypertension is a multifactorial disease and the relative contribution by noise is probably quite small compared to other factors.

Association between aircraft noise level and the prevalence or incidence of hypertension (Babisch 2008)
Results of epidemiological studies on the association between traffic noise and coronary (ischaemic) heart disease (Babisch 2002, 2004)
Myocardial infarction

- Epidemiological studies have also suggested a higher risk of coronary heart disease and myocardial infarction, in subjects who were chronically exposed to high levels of road traffic noise.

Exposure-response curve for road traffic noise level ($L_{day,16h}$) and incidence of myocardial infarction (Babisch 2008)
Road traffic noise and myocardial infarctions

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

Source: WHO Night Noise Guidelines for Europe 2009 / Babisch
Hearing impairment

- **Inner ear lesions** caused by noise
- Not so common effect of environmental noise, mainly caused by **occupational noise**
An example of hearing impairment caused by noise as an alteration of mean hearing level.
Noise effects in different population groups

• Noise and children

• Noise sensitive individuals
Environmental noise and children

• Sound environments:
  • home, day care center (kindergarten), school, leisure time

• Children at risk:
  • other developmental problems and delays
  • bi - multilingualism
  • social deprivation
  • chaotic environment
  • other health problems
  • noise sensitivity
Noise sensitivity

• A measure of attitudes to noise in general

• A predictor of noise annoyance

• Noise sensitive individuals are more affected by noise than less sensitive individuals
  They pay more readily attention to noise, perceive more threat from noise and may react more to noise than less sensitive individuals.

• The risk of health effects caused by noise may be higher for noise sensitive individuals
Model of the schematic pathways of the possible relationship of noise sensitivity with development of cardiovascular disease.

1. Noise sensitivity
   - Inherited characteristics
   - CNS auditory pathways

2. Noise
   - Annoyance
   - Stress
   - Sleep disturbance
   - Activation of the sympathetic-adrenal-medullary (SAM) and hypothalamic-pituitary-adrenal (HPA) axels
   - Increase of blood pressure, heart rate, peripheral resistance
   - Long-term noise exposure

3. Cardiovascular diseases
   - Inherited characteristics
   - Other risk factors (e.g., lifestyle)
Noise sensitivity questionnaires

- Short questions like “People experience noise in different ways. Do you experience noise generally as very disturbing, quite disturbing, not especially disturbing, not at all disturbing or can’t say?”

  Subjects answering “very disturbing” and “quite disturbing” are classified as noise sensitive (high and quite high noise sensitivity)

  Subjects answering “not especially disturbing” and “not at all disturbing” are classified as non-noise sensitive (quite low and low noise sensitivity)

- The Weinstein’s Noise Sensitivity Scale
Occurrence and stability of noise sensitivity

• The percentage of noise sensitive subjects has varied between 20 % and 43 % in different studies

• In a Finnish study 38 % were noise sensitive

• Noise sensitivity is a quite stable trait

(Heinonen-Guzejev et al. 2004)
Association of noise sensitivity with somatic and psychological factors

- Noise sensitivity is associated with hypertension
- use of psychotropic drugs (sleeping pills, tranquillizers and pain relievers)
- stress
- hostility
- smoking
- emphysema

(Heinonen-Guzejev et al. 2004)
Mean number of total health complaints in relation to noise (inside the living room), gender and degree of noise sensitivity (Nivison 1992)
Association of noise sensitivity with cardiovascular mortality

- Cardiovascular mortality has been significantly increased among noise sensitive women

- In women the interaction of noise sensitivity and lifetime noise exposure has been statistically significant for coronary heart mortality; Among men no statistically significant effects

(Heinonen-Guzejev et al. 2007)
Genetic component of noise sensitivity

- **Aggregates in families** and probably has a genetic component

- The best fitting genetic model provided an estimate of heritability of 36%

  *(Heinonen-Guzejev et al. 2005)*
### WHO guideline values for community noise in specific environments

<table>
<thead>
<tr>
<th>Specific environment</th>
<th>Critical health effect(s)</th>
<th>LAeq [dB]</th>
<th>Time base [hours]</th>
<th>LAmx, fast [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor living area</td>
<td>Serious annoyance, daytime and evening</td>
<td>55</td>
<td>16</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Moderate annoyance, daytime and evening</td>
<td>50</td>
<td>16</td>
<td>-</td>
</tr>
<tr>
<td>Inside bedrooms</td>
<td>Speech intelligibility and moderate annoyance, daytime and evening</td>
<td>35</td>
<td>16</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Sleep disturbance, night-time</td>
<td>30</td>
<td>8</td>
<td>45</td>
</tr>
<tr>
<td>Outside bedrooms</td>
<td>Sleep disturbance, window open (outdoor values)</td>
<td>45</td>
<td>8</td>
<td>60</td>
</tr>
<tr>
<td>School class rooms</td>
<td>Speech intelligibility, disturbance of information extraction, message communication</td>
<td>35</td>
<td>during class</td>
<td>-</td>
</tr>
<tr>
<td>and pre-schools, indoors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-school bedrooms, indoors</td>
<td>Sleep disturbance</td>
<td>30</td>
<td>sleeping -time</td>
<td>45</td>
</tr>
<tr>
<td>School, playground outdoor</td>
<td>Annoyance (external source)</td>
<td>55</td>
<td>during play</td>
<td>-</td>
</tr>
<tr>
<td>Hospital, ward rooms, indoors</td>
<td>Sleep disturbance, night-time</td>
<td>30</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Sleep disturbance, daytime and evenings</td>
<td>30</td>
<td>16</td>
<td>40</td>
</tr>
<tr>
<td>Hospitals, treatment rooms, indoors</td>
<td>Interference with rest and recovery</td>
<td>#1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial, commercial, shopping and traffic areas, indoors and Outdoors</td>
<td>Hearing impairment</td>
<td>70</td>
<td>24</td>
<td>110</td>
</tr>
<tr>
<td>Ceremonies, festivals and entertainment events</td>
<td>Hearing impairment (patrons:&lt;5 times/year)</td>
<td>100</td>
<td>4</td>
<td>110</td>
</tr>
<tr>
<td>Public addresses, indoors and outdoors</td>
<td>Hearing impairment</td>
<td>85</td>
<td>1</td>
<td>110</td>
</tr>
<tr>
<td>Music through headphones/Earphones</td>
<td>Hearing impairment (free-field value)</td>
<td>85 #4</td>
<td>1</td>
<td>110</td>
</tr>
<tr>
<td>Impulse sounds from toys, fireworks and firearms</td>
<td>Hearing impairment (adults)</td>
<td>-</td>
<td>-</td>
<td>140 #2</td>
</tr>
<tr>
<td></td>
<td>Hearing impairment (children)</td>
<td>-</td>
<td>-</td>
<td>120 #2</td>
</tr>
<tr>
<td>Outdoors in parkland and conservation areas</td>
<td>Disruption of tranquillity</td>
<td>#3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#1: as low as possible; #2: peak sound pressure, measured 100 mm from the ear; #3: existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low; #4: under headphones, adapted to free-field values
Thank you for your attention!