Transportation noise: Health threat or just annoying?

Martin Röösli, 09 March 2022

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@MartinRoosli
Content

- Sound processing
- From sound to noise
- Annoyance
- Cardiovascular effects
- Diabetes, depression, behaviour cognition
- New proposal for Swiss noise regulation
Sound processing

«The ear never sleeps»

Source: https://www.pinterest.ch/pin/463589355378054573/
Sound

- **Sound** ≡ any pressure variation that the human ear can detect measured in decibels (dB); 0 dB ‘threshold of hearing’ (20 μPa) – 130 dB ‘threshold of pain’ (~100Pa).

- **Logarithmic**: increase of 3 dB corresponds to a doubling of the sound pressure ($10^{3\text{dB}/10}=2$)

- **Noise** ≡ audible sound that causes disturbance, impairment or health damage

- $L_{den}$: Average sound level over all 24 hour periods of a year, with a penalty of 5 dB added for the evening hours penalty of 10 dB added for the night hours

**COMMON INDOOR/OUTDOOR NOISE LEVELS**

- Whisper: 20 dB
- Normal speech 3 ft: 65 dB
- Quiet Urban Neighbourhood: 50 dB
- Traffic Noise 50 ft: 70 dB
- Train Horn: 90 dB
- Jet take off 1,600 ft: 100 dB
- Rock Music: 110 dB
- Chainsaw: 120 dB

From Seminole Manor
Stress Model

Lärm (german) ≡ alarm <
-> all'arme (ital.): to take up rms/weapons

Hypothalamic-pituitary-adrenal axis (HPA)

Sympathetic nervous system-adrenal medullary axis (SNA)

Recio et al, 2016
Noise annoyance

Representative survey in Switzerland (SiRENE), n= 5'592

Highly annoyed

Wenn Sie an die letzten 12 Monate bei Ihnen denken, welche Zahl zwischen 0 und 10 gibt am besten an, wie stark Sie sich durch Lärm von <Lärmart> insgesamt gestört oder belästigt fühlten?

%HA

\[ L_{\text{den}} \text{ [dB]} \]

Brink, Env Int, 2019

= highly annoyed (HA)
Factors affecting noise annoyance

- Level
- Timing (e.g. night or day)
- Feeling of control (e.g. own sound, predictability)
- Characteristics of sound such as tone, impulse etc.
- Attitude to the source
- Distance and orientation to the source
Noise and cardiometabolic effects

Schmid et al, 2015

adapted from Hahad et al, 2019
Swiss National Cohort (2000-2015)

- All inhabitants in Switzerland (4.41 million people aged >30 years)
- Mortality records and census data linked
  - Sex, civil status, education, mother tongue, nationality
  - Neighborhood, community and regional socio-economic position and unemployment rate
  - Noise: road, railway, aircraft
  - Air pollution (PM2.5)
Noise vs. cardiovascular and myocardial infarction mortality

WHO guidelines
Risk increase
Noise distribution

Vienneau et al, Env Int, 2022
Noise vs. cardiovascular and myocardial infarction mortality

<table>
<thead>
<tr>
<th>Source</th>
<th>Excess risk per 10 dB (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{\text{den}}$ Road</td>
<td>2.9 (2.4-3.4)</td>
</tr>
<tr>
<td>$L_{\text{den}}$ Railway</td>
<td>1.3 (1.0-1.7)</td>
</tr>
<tr>
<td>$L_{\text{den}}$ Aircraft</td>
<td>0.3 (-0.4-1.0)</td>
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</tbody>
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<th>Excess risk per 10 dB (%)</th>
</tr>
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<tbody>
<tr>
<td>$L_{\text{den}}$ Road</td>
<td>4.3 (2.9-5.8)</td>
</tr>
<tr>
<td>$L_{\text{den}}$ Railway</td>
<td>2.0 (1.0-3.0)</td>
</tr>
<tr>
<td>$L_{\text{den}}$ Aircraft</td>
<td>4.0 (2.0-6.0)</td>
</tr>
</tbody>
</table>

Vienneau et al, Env Int. 2022

WHO guidelines
Neurobiological mechanism  (Osborne, EHJ, 2020)

- In 498 adults (N= 498) without CVD or active cancer, amygdalar metabolic activity and heightened arterial inflammation were measured, transportation noise at home modelled.
- 40 major adverse cardiovascular disease events (MACE) occurred within 4 years.
Acute cardiovascular effects?

Does night-time aircraft noise trigger mortality? A case-crossover study on 24,886 cardiovascular deaths

Apolline Saucy 1,2, Beat Schäffer 3, Louise Tangermann 1,2, Danielle Vienneau 1,2, Jean-Marc Wunderli 3, and Martin Röösli 1,2*

1Department of Epidemiology and Public Health, Swiss Tropical and Public Health Institute, Socinstrasse 57, Basel 4002, Switzerland; 2Faculty of Science, University of Basel, Petersplatz 1, Basel 4032, Switzerland; and 3Empa, Swiss Federal Laboratories for Materials Science and Technology, Überlandstrasse 129, Dübendorf 8600, Switzerland

Received 29 July 2020; revised 6 October 2020; editorial decision 4 November 2020; accepted 11 November 2020; online publish-ahead-of-print 30 November 2020

See page 844 for the editorial comment on this article (doi: 10.1093/eurheartj/ehaa984)
A case-crossover study around Zurich Airport

24,886 cases of cardiovascular death (2000-2015)
Swiss National Cohort

Can night-time aircraft noise trigger cardiovascular mortality?

Or cold, heat, air pollution?

Study population and runway system at Zurich Airport

Exposure data
- Aircraft noise
- Air pollution
- Temperature
- Precipitation

Slide: Apolline Saucy
Nighttime deaths: noise exposure within 2 hours of death

- Continuous increase in risk for all CVD and arrhythmias
- Indications for a thresholds for ischaemic heart diseases, myocardial infarction and heart failure
- No association between nighttime noise and daytime deaths

Conditional logistic regression adjusted for NO2, temperature, precipitation, and holiday

Saucy et al, EHJ, 2021
SAPALDIA
Swiss study on Air Pollution and Lung Disease in adults

• Outcome
  **Diabetes**: 110 incident cases between 2001 and 2011 in 2'631 persons
  **Depression**: 410 incident cases between 2001 and 2011 in 4'581 persons
  (Respiratory diseases, arterial stiffness)

<table>
<thead>
<tr>
<th>Source</th>
<th>Relative Risk per 10dB (%)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{den}$ road</td>
<td>1.35</td>
<td>1.02</td>
</tr>
<tr>
<td>$L_{den}$ air</td>
<td>1.86</td>
<td>0.96</td>
</tr>
<tr>
<td>$L_{den}$ railway</td>
<td>0.94</td>
<td>0.71</td>
</tr>
</tbody>
</table>

• Statistical analysis
  Multi-exposure model for $L_{den}$ (road, rail, air) adjusted for many socio-demographic and lifestyle factors (e.g. smoking, alcohol, physical activity etc.) as well as air pollution.

*Eze et al. Int J Epidemiol, 2017*
Exposure-response

Meta-analysis

Vienneau et al., 2019
Randomized human experiment in the sleep laboratory: glucose response to a morning oral glucose tolerance test (OGTT)

Thiesse et al. Env Int, 2018
### Depression

#### Sapaldia

<table>
<thead>
<tr>
<th>Source</th>
<th>Relative Risk pro 10dB (%)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>L_{den} road</td>
<td>1.07</td>
<td>0.93</td>
</tr>
<tr>
<td>L_{den} air</td>
<td>1.20</td>
<td>0.92</td>
</tr>
<tr>
<td>L_{den} railway</td>
<td>0.88</td>
<td>0.76</td>
</tr>
</tbody>
</table>

_Eze et al. Environ Int, 2020_
Community noise exposure above Lden of 70 dB(A) and Lnight of 60 dB(A) is associated with behavioural problems and cognitive development in a cohort of 3385 preschool children in Sao Paulo.

METHOD

Noise measurements in Sao Paulo

Land use regression model

Noise map

Noise distribution

A  Lden (mean=69 dB)

B  Lnight (mean=60 dB)

Behavioral Problems

- 3 years: Strengths and Difficulties Questionnaire (SDQ)
- 6 years: Child Behavior Checklist (CBCL)

Cognitive Development

- 3 years: PRIDI
- 6 years: IDELA

Multivariable cross-sectional and longitudinal regression models

OUTCOME

Lden vs. behavior at age 3y

Lden vs. behavior at age 6y

Intermediate conclusions

• In Europe, noise is the 2. most relevant environmental health burden after air pollution.
• Still relatively little research and little awareness (unless personally affected).
• Good evidence for effects on coronary heart diseases from chronic noise exposure.
• Substantial indications for other cardiovascular disease, diabetes, obesity, depression as well as behavioural problems and cognitive development in children.
• Indications for acute cardiovascular damage.
• Little habituation to noise from physiological point of view.
• Health effects occur also in people who are not noise annoyed.
Environmental noise in Europe — 2020

Map 2.1 Estimated percentage of inhabitants within urban areas, exposed to road noise levels $L_{an}$ ≥ 55 dB in 2017

- Estimated percentage of inhabitants within urban areas exposed to road noise levels $L_{an}$ ≥ 55 dB
  - < 15
  - 15-30
  - 30-50
  - 50-65
  - 65-75
  - > 75

No data
Outside coverage
Health Impact in Europe

At least 20% of the EU population live in areas where traffic noise levels are harmful to health. These significant health impacts are most likely to be underestimated, with new WHO evidence...
External costs of noise

One day, mankind will fight noise as relentlessly as Cholera and the Pest.

Robert Koch (1843 - 1910)

Source: de.wikipedia.org
### WHO noise guidelines for the European Region, 2018

<table>
<thead>
<tr>
<th>Source</th>
<th>night</th>
<th>Lden</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>45 dB</td>
<td>53 dB</td>
</tr>
<tr>
<td>Railway</td>
<td>44 dB</td>
<td>54 dB</td>
</tr>
<tr>
<td>Aircraft</td>
<td>40 dB</td>
<td>45 dB</td>
</tr>
<tr>
<td>Wind turbine</td>
<td>-</td>
<td>45 dB</td>
</tr>
</tbody>
</table>

**Swiss regulatory limits:**
- **night:** 45-60 dB
- **Day:** +10 dB
Federal Noise Abatement Commission has proposed new noise limits in 2021
“Preliminary study to review the immission limit values for noise”

2008: EKLB/BAFU initiates

2009: Synthesis report

2010: Concept study with work packages + financial needs

2010: Research concept EKLB

2011: No funding through UVEK resources

2013-2020 Sinergia application 2013

2014-2018

Swiss noise ordinance (LSV): 1987
(Limits: road rail: 1987, aircraft: 2001)

A long journey...
Legal basis

• Federal Constitution Art. 74 - Environmental protection
  The Confederation shall issue regulations on the protection of humans and their natural environment from harmful or annoying effects.

• Environmental law Art. 15 - ambient limit values for noise and vibrations
  The limit values for noise and vibrations shall be set in such a way that, according to the state of scientific knowledge or experience, exposure below these values do not significantly disturb the well-being of the population.

• Environmental law Art. 13 – ambient limits
  It shall also take into account the effects on vulnerable groups of people, such as children, the sick, the elderly and pregnant women.
Deriving limits: the challenge

WHO-guidelines (53 dB)

Non-parametric exposure-response curve

Histogram: Distribution of road traffic noise in CH

Threshold?

General approach

Same approach as WHO

Vienneau et al, 2022
Methods

- **Science-based** and objective derivation with the same approach as the WHO in the development of the "Environmental Noise Guidelines“, 2018.
- Separate assessment of **road, rail and aircraft noise**.
- **Subjectively perceived** noise effects are relevant to health and have the same weight as **somatic** health effects.

![Noise exposure diagram](image-url)
Deriving scientific evidence

• Evidence evaluation criteria:
  ▪ Causal relationship plausible from a pathophysiological point of view, evidence evaluation criteria WHO.
  ▪ Solid exposure-response relationships exist.
  ▪ In addition to international studies, there is at least one good-quality study from Switzerland.
  ▪ Results from Swiss studies do not contradict the results from international meta-analyses (and vice versa).

• Derivation of exposure-response relationships for each outcome:
  ▪ Meta-analysis of international data (50% weight)
  ▪ Swiss study data (50% weight)
Accepted risks

Nuisance (self-reported)

- Noise annoyance
  - 25% highly annoyed
- Sleep disturbance
  - 15% highly sleep disturbed

Diseases

- Cardiovascular system
  - 5% ischemic heart disease incidence
  - 2.5% cardiovascular mortality
- Diabetes
  - 20% diabetes incidence
## Definition of thresholds

**Road traffic: 25% HA**

Brink et al, 2019
(https://doi.org/10.1016/j.envint.2019.01.043)

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**Road traffic: 2.5% increase in CVD mortality**

Heritier et al, 2017
(https://doi.org/10.1007/s10654-017-0234-2)
Evidence synthesis

Nuisance

%HSD/%HA
SiRENE

%HSD/%HA
Update WHO Review

Mean value
$L_{den}/L_{night} [dB]$

Dis ease

Cardiovasc. mortality
SiRENE

IHD
Update WHO Review

Diabetes
SiRENE
Update WHO Review

Mean value
$L_{den}/L_{night} [dB]$

Lower of each mean value

### Overview Regulatory limits

<table>
<thead>
<tr>
<th></th>
<th>CH day</th>
<th>CH night</th>
<th>WHO Lden</th>
<th>WHO night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>60</td>
<td>52</td>
<td>53</td>
<td>45</td>
</tr>
<tr>
<td>Railway</td>
<td>59</td>
<td>56</td>
<td>54</td>
<td>44</td>
</tr>
<tr>
<td>Aircraft</td>
<td>54</td>
<td>43*</td>
<td>45</td>
<td>40</td>
</tr>
</tbody>
</table>

#### Relevant effects

- **Nuisance**
- **Adverse effects**
- **Nuisance and adverse effects**

*Night hours aircraft (flight curfew: 0.00-5.00):

<table>
<thead>
<tr>
<th>Time</th>
<th>Lden</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.00-23.00</td>
<td>52 dB</td>
</tr>
<tr>
<td>23.00-24.00</td>
<td>49 dB</td>
</tr>
<tr>
<td>05.00-06.00</td>
<td>49 dB</td>
</tr>
<tr>
<td>06.00-07.00</td>
<td>52 dB</td>
</tr>
</tbody>
</table>
Additional recommendations

• Application
  Focus on residential; more flexible for rooms without long-term residential purpose (office, hotel)

• Point of measurement
  Loudest point on facade ➔ Pressure on mitigations measures at source

• Time periods
  Extension of the night period to 9 hours (22-07 h) ➔ Protection of sleep
  Additional single hour limit between 06 and 07 o'clock for aircraft noise

• Uniform protection of residential areas
  Same limits in sensitivity areas II and III

• No corrections due to little traffic
  ➔ Road and railways noise
Summary of proposed new noise guidelines

- The recommendation is based on the current state of scientific knowledge.
- The proposed limit values protect the population better from noise.
- The health consequences of traffic noise cause CHF 2.8 billion in external costs every year. Investments in noise protection are worthwhile.
- Noise abatement at the source is central.

The existing limits for traffic noise underestimate the negative effects of noise on the population and no longer meet the requirements of the Environmental Protection Act.

➔ Report is with the Federal Council
Noise mitigation at the source

**Traffic management**
- dbR: 1–4 dB

**Noise barriers**
- dbR: 3–20 dB

**Brake blocks for trains**
- dbR: 8–10 decibels (dB)

**Building insulation**
- dbR: 5–10 dB

**Building design**
- dbR: 2–15 dB

**Land-use planning & design**
- dbR: Unknown

**Low-noise tyres**
- dbR: 3–4 dB

**Quiet road surfaces**
- dbR: 3–7 dB

**Changing driving styles**
- dbR: 5–7 dB

**Electric cars**
- dbR: -1 dB

**Implementation**:
- Over 3,000 km of noise barriers have been installed alongside European rail networks. They are even more widely used alongside roads, including in Austria, Denmark, France, Germany, Italy, Poland, Spain & the Netherlands.

- Traffic management strategies are widely used across Europe. In Paris & Valencia there is restricted access for heavy goods vehicles, while Amey & Parma have implemented shuttle bus services to reduce private car use.

- Electric cars have the potential to reduce noise.

- Computer models can predict noise exposure & identify areas unsuitable for development. No houses should be allowed under landing and take-off, for instance.

- Several have been developed & are on sale on the European market.

**Implementation**:
- European freight trains are being retrofitted with low-noise brake blocks. A complete ban on ‘noisy’ cast iron blocks is due to take place in Germany, the Netherlands & Switzerland in 2020.

- A Norwegian study of façade insulation found an average noise reduction of 7 dB inside buildings & a 30% reduction in annoyance.

- It is unclear how widely acoustical architectural planning is used. Administrative action is needed for large-scale use.

- Quieter driving could be incorporated into existing campaigns promoting ‘eco-driving’ to save fuel & reduce air pollution (e.g., http://www.ecodriver.org).

- Low-noise surfaces have been trialed in Denmark, France, Italy, the Netherlands & UK. New applications include using rubber from end-of-life tyres, following a circular-economy approach.

Thank you for your attention

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