Chronic health effects and injury associated with environmental noise pollution

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Centers for Disease Control and Prevention, 17 May 2018
Introduction to noise pollution

- Substantial adverse public health impacts
  - Likely among most common exposures

- Treated differently than other pollutants
  - Air, water, soil, food, etc
  - Ignored in US for 40 yrs

https://ephytracking.cdc.gov/showRiskLandingSolution.action
Noise exposure: measurements

- Area measurements
- Personal measurements
- Models
- Usually focus on average or maximum exposure
Units: decibels (dB)

A-weighting typically used
Noise exposure: quantification

• Equivalent continuous noise level \( (L_{EQ}) \) is foundation of noise exposure assessment

https://www.fhwa.dot.gov/Environment/noise/regulations_and_guidance/analysis_and_abatement_guidance/fig1.gif
Common environmental noise metrics

1. $L_{EQ}$
   - Assumes all periods contribute equally to risk

2. $L_{DN}$ (Day-Night Level)
   - $L_{EQ}$ with 10 dB penalty added for nighttime noise (10 PM to 7 AM)
   - Accounts for increased sensitivity/disruption at night
What do we know about US occupational noise?

- Occupational Safety and Health Administration (OSHA) measurements
  - ~750,000 Permissible Exposure Limit (PEL)
  - ~320,000 Action Level (AL)

Sayler et al, manuscript submitted
What do we know about US environmental noise?

• From 1981 until very recently, not much

• Several efforts in last recent years have shed light on ambient noise levels in US
  – Additional efforts at local (i.e., city) level

• Most efforts based on modeling; few on measurements

EPA, 1981
Why differentiate modeling from measurements?

All models are wrong; some models are useful
- George Box, "Statistics for Experimenters", 2005
Noise map: modeled road and air, dBA

https://www.transportation.gov/highlights/national-transportation-noise-map
Noise map: modeled road and air, dBA

https://www.transportation.gov/highlights/national-transportation-noise-map
Noise map: modeled road and air, dBA

https://www.transportation.gov/highlights/national-transportation-noise-map
Noise map: modeled conditions, dBA

https://www.nps.gov(subjects/sound/soundmap.htm
Noise map: modeled...?
Noise map: modeled road, dBA

http://maps.sfplanning.org/Noise.pdf
Noise map: measured, dBA

A-weighted Sound Levels (dBA): DAY

http://boston.noiseandthecity.org/a-weighted-sound-levels-by-dba-day
Noise map: measured, dBA

Noise maps are great.
But they will never be enough

- Do not account for variations in behavior, activities
- Do not estimate personal exposures
- Often do not account for temporal variability
- Questionable assumptions, validation?
If you remember nothing else today…

- Three *equally important* components for *any* environmental exposure
  - Exposure frequency (how often)
  - Exposure duration (how long)
  - Exposure intensity/level (how much)

- Without information about all three, cannot estimate health risk
Personal monitoring gets us all three

91% of 4436 NYC subjects > EPA limit from all noise sources combined and at risk of NIHL; mean 76.8 dBA

Noise maps would suggest exposures of 55-80 dBA

EPA recommended annual limit

What personal monitoring shows

Primary exposure source for 59% of 4436 subjects = music!

Conclusions: noise exposure

- Need better estimates of noise exposure in US
- Use combination of mapping and personal measurements
- Exposure estimates essential to evaluate public health impacts

Hammer et al, *Environ Health Persp*, 2014
Health effects of environmental noise

- Noise-induced hearing loss (duh)
- Cardiovascular disease (ischemic heart disease, hypertension)
- Injuries?
- Diabetes and/or endocrine disruption?
- Psychological/mental health effects?
- Cognitive effects?

https://www.pinterest.com/pin/464081936578774649/
Noise-induced hearing loss (NIHL)

- Chronic exposures cause metabolic damage to cochlea, eventual cell death
  - Neuronal destruction possible → adequate detection, poor understanding
  - Well-understood dose-response; risk begins at 70 dBA $L_{EQ}(24)$

- Mechanical damage (acoustic trauma)

- Tinnitus and hyperacusis

www.osha.gov/dts/osta/otm/new_noise/
NIHL in US children

Su et al, JAMA-OHNS, 2011
NIHL in US adults

FIGURE. Percentage of persons with unilateral (in one ear) and bilateral (both ears) audiometric notches* in audiograms among adults aged 20–69 years who reported exposure to loud or very loud noise at work and those who reported no noise exposure at work, by sex — National Health and Nutrition Examination Survey, United States, 2011–2012

Audiometric test findings

<table>
<thead>
<tr>
<th>Audiometric test findings</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral notch with work exposure</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>Unilateral notch with no work exposure</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Bilateral notch with work exposure</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Bilateral notch with no work exposure</td>
<td>5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

CDC, *MMWR*, 2017

Figure. Prevalence of Speech-Frequency Hearing Impairment (HL) by Age, NHANES 1999-2004 vs 2011-2012

A. Woman, better ear

B. Men, better ear

C. Woman, worse ear

D. Men, worse ear

Economic impacts of NIHL

- HL in estimated 13.4% of working population
- Impacts on those with HL
  - Reduced wages (25% less than normal hearing)
  - 2.5 times as likely to be unemployed
- If the 20% of HL from noise were prevented
  - $58-152B benefit annually ($123B core estimate)
- Conservative; does not consider additional costs
  - Health care and special education

Neitzel et al, JSLHR, 2017
Noise and cardiovascular disease

Babisch W, *Noise Health*, 2004
Evidence for noise $\rightarrow$ CVD

• Consistent associations
  – Mainly hypertension, myocardial infarction
  – Mixed study designs, locations, durations
  – Mainly airport, road noise
  – Effects start at 45-55 dBA $L_{DN}$
  – Occupational evidence, too

• Strong evidence from Europe

CVD from noise impacts in US

- Estimated CVD savings from 5 dB reduction in US population noise in 2014: $3.9 billion

**Table 3. Model Results**

<table>
<thead>
<tr>
<th>Model</th>
<th>Current situation</th>
<th>5-dB reduction scenario estimate</th>
<th>Difference (current – reduction scenario)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1: coronary heart disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of people exposed ≥ 55 dBA L_{eq}</td>
<td>145.5 million</td>
<td>0</td>
<td>-145.5 million</td>
</tr>
<tr>
<td>Number of affected individuals</td>
<td>15.4 million</td>
<td>15.1 million</td>
<td>-279,000</td>
</tr>
<tr>
<td>Population risk (%)</td>
<td>4.89</td>
<td>4.80</td>
<td>-0.09</td>
</tr>
<tr>
<td>Annual cost, direct ($)</td>
<td>96 billion</td>
<td>94.3 billion</td>
<td>-1.7 billion</td>
</tr>
<tr>
<td>Annual cost, indirect ($)</td>
<td>81.1 billion</td>
<td>79.8 billion</td>
<td>-1.5 billion</td>
</tr>
<tr>
<td>Model 2: hypertension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of people exposed ≥ 55 dBA L_{eq}</td>
<td>145.5 million</td>
<td>0</td>
<td>-145.5 million</td>
</tr>
<tr>
<td>Number of affected individuals</td>
<td>77.9 million</td>
<td>76.7 million</td>
<td>-1.2 million</td>
</tr>
<tr>
<td>Population risk (%)</td>
<td>24.7</td>
<td>24.3</td>
<td>-0.4</td>
</tr>
<tr>
<td>Annual cost, direct ($)</td>
<td>47.5 billion</td>
<td>46.8 billion</td>
<td>-884 million</td>
</tr>
<tr>
<td>Annual cost, indirect ($)</td>
<td>3.5 billion</td>
<td>3.4 billion</td>
<td>-50 million</td>
</tr>
</tbody>
</table>

Noise and injuries

INDEPENDENT FACTOR

Hazardous physical activity
Noise exposure

MODERATING FACTORS

Fatigue
Stress
Hearing loss or communication difficulty

OUTCOME

Injury

Neitzel, manuscript in preparation
Evidence for noise $\rightarrow$ injuries

- Moderate evidence from occupational cohort studies
  - Mixed study designs, locations, durations
  - Acute injuries, mild to serious
  - Consistent associations
  - Effects start $\sim$85 dBA 8-hr $L_{EQ}$

- Environmental noise studies lacking

Noise and diabetes

The Vehicular Traffic and Obesity/Metabolic Syndrome Pathway

Noise and diabetes

• Few studies, many ecological study design
  – 10 dB increase in long-term road noise increased risk of diabetes in Denmark (Sørensen et al, Environ Health Persp, 2013)
  – No clear associations between long-term air traffic noise and diabetes (Eriksson et al, Environ Health Persp, 2014)

• Some evidence, no clear threshold
Noise and mental health effects

Figure 1. Conceptual model of the interaction of noise with humans and the occurrence of effects on health and quality of life (2).

Evidence for noise \(\rightarrow\) mental health

- Few studies, limited range of designs
- Several studies showed increased behavioral problems in children exposed to noise
- One study showed increased dementia-related emergencies with higher noise
- Some evidence, no clear threshold

Orban et al, Environ Health Persp, 2016
Noise and cognitive effects

Evidence for noise → cognitive effects

• Limited number of studies, primarily on children
• Several show reduced reading comprehension, memory, executive function with increased noise
• Moderate evidence, no clear threshold

Elmenhorst et al, *Int Arch Occup Environ Health, 2010*
CDC systematic review of noise effects

- Hearing loss
- Ischemic heart disease
- Hypertension
- Psychological or mental health issues
- Injuries
- Endocrine disruption

- Cancer/tumorigenesis
- Cognition
- Sleep disturbance
- Low birthweight or premature birth
- Obesity/overweight
Goals of systematic review

• Evaluate association between noise exposure and each health impact
  – What noise levels, and for how long, are associated with each health impact?

• Evaluate strength of evidence

• Recommend “safe” exposure limits

Example “safe” NIHL exposure limits

- Occupational Safety and Health Administration
  - 8-hr Permissible Exposure Limit of 90 dBA
  - Will result in NIHL in >25% of individuals after 40 years

- National Institute for Occupational Safety and Health
  - 8-hr Recommended Exposure Limit of 85 dBA
  - Will result in NIHL in 8% of exposed individuals after 40 years
Example “safe” NIHL exposure limits

• European Union
  – 8-hour Lower Action Value of 80 dBA
  – Will result in NIHL in <1% of individuals after 40 years

• Environmental Protection Agency/World Health Org.
  – 24-hr recommended limit of 70 dBA
  – Completely protective against NIHL after 40 years, but…
“Safe” limits for other health effects

- WHO has recommendations to protect against other effects
  - Sleep disturbance, speech intelligibility, annoyance

- ACGIH* noted in 2018 that CVD possible <85 dBA, injuries >85 dBA 8-hr occupational exposure

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*American Conference of Governmental Industrial Hygienists

WHO, 1999
Conclusions

• Need to protect public health
  – Exposures substantial, widespread, cumulative across sources and lifetime

• Exposure assessment challenging

• Health impacts extend beyond NIHL

• Exposure limits and interventions needed to improve health

http://sunnyspellsandscatteredshowers.org/tip-of-the-iceberg/
For More Information

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• University of Michigan Exposure Research Lab
  – https://umexposureresearch.org/