Chronic health effects and injury associated with environmental noise pollution

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SCHOOL OF PUBLIC HEALTH
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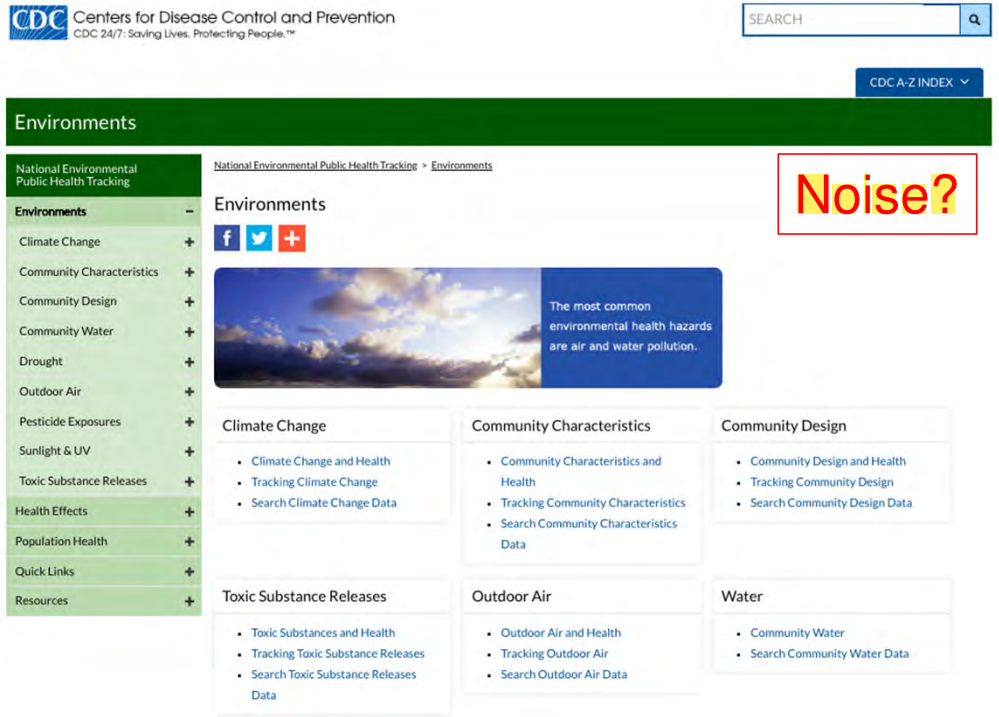
Introduction to noise pollution

- 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

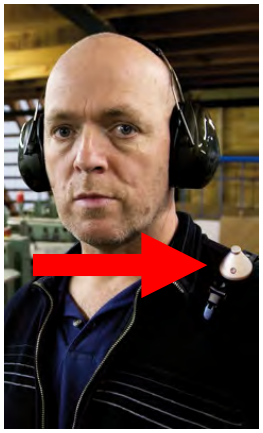
CDC National Environmental Public Health Tracking

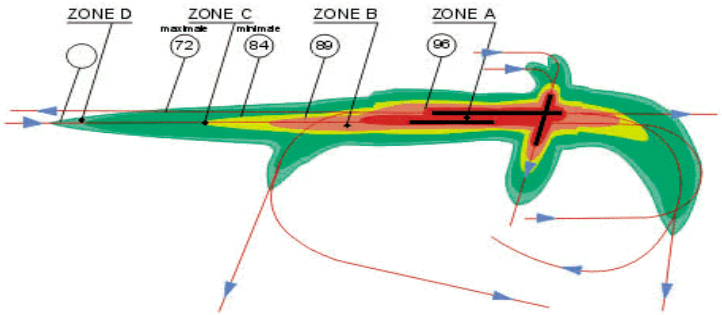


https://ephtracking.cdc.gov/showRiskLandingSolution.action

Noise exposure: measurements

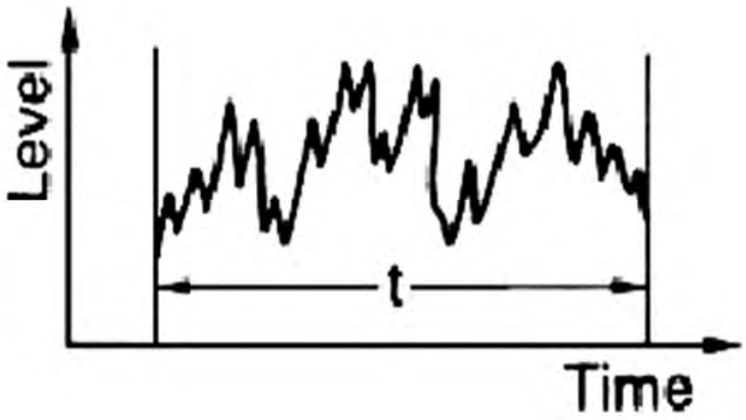
- Area measurements
- Personal measurements
- Models
- Usually focus on average or maximum exposure

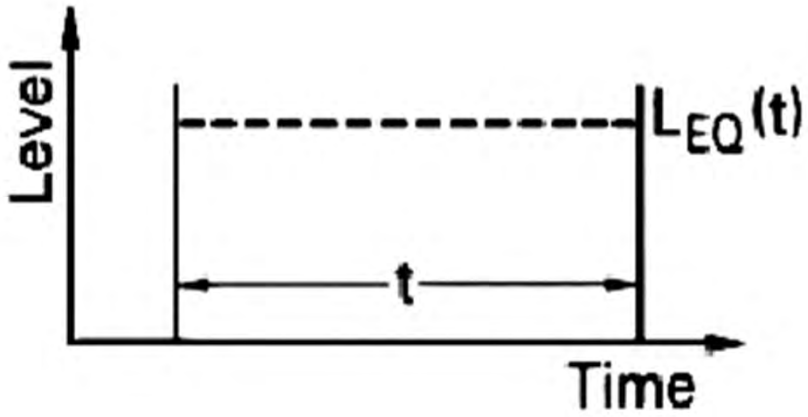




Noise exposure: quantification

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

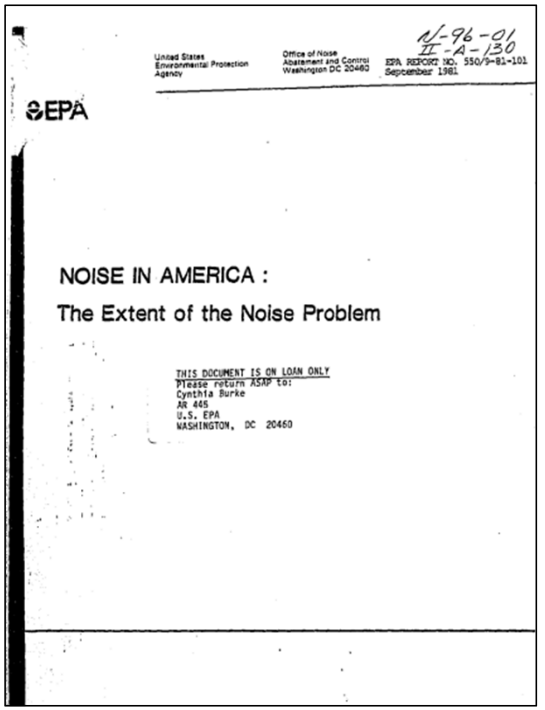




https://www.fhwa.dot.gov/Environment/noise/regulations_and_guidance/analysis_and_abatement_guidance/fig1.gif

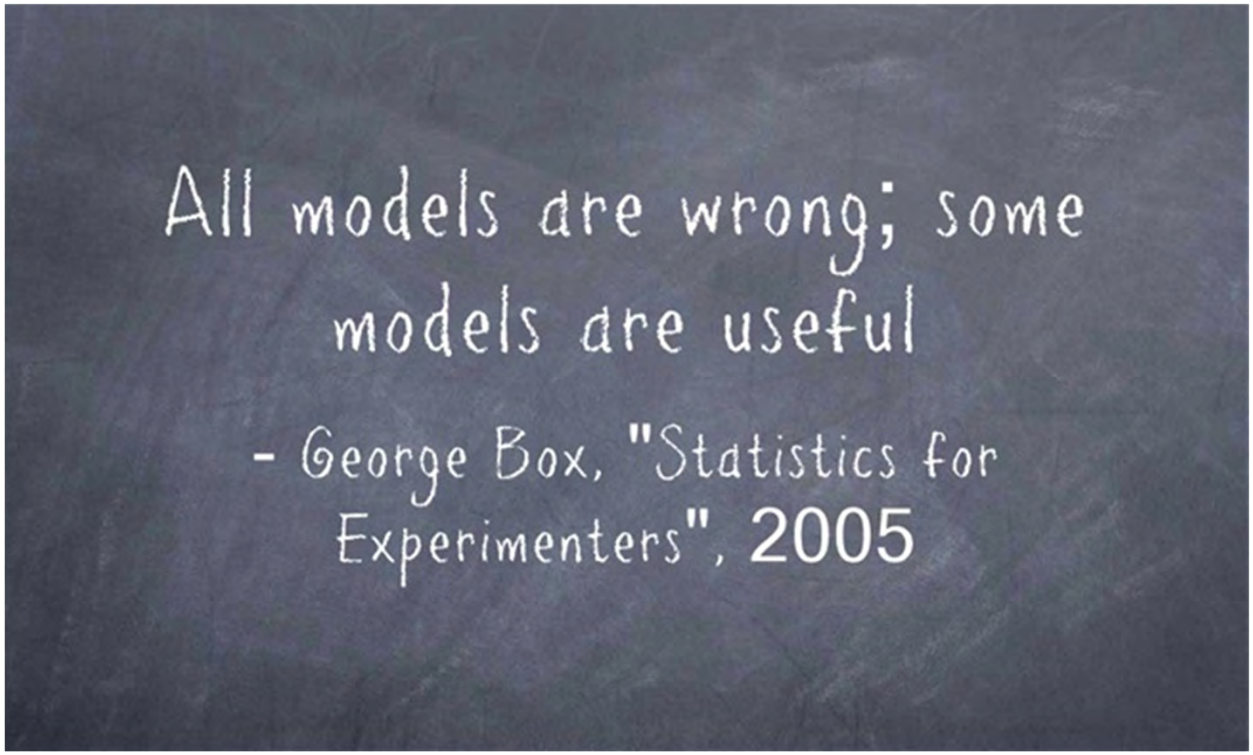
What do we know about US environmental noise?

- 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

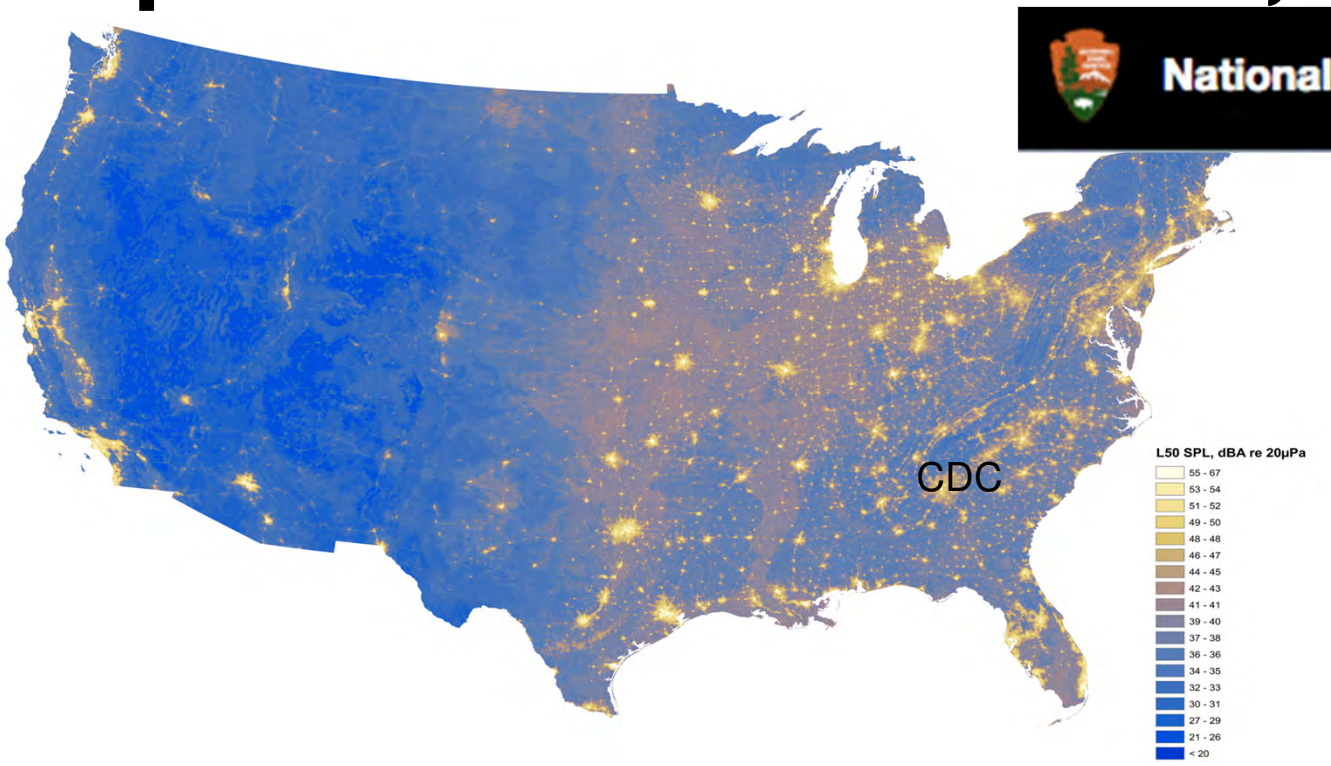


EPA, 1981

Why differentiate modeling from measurements?



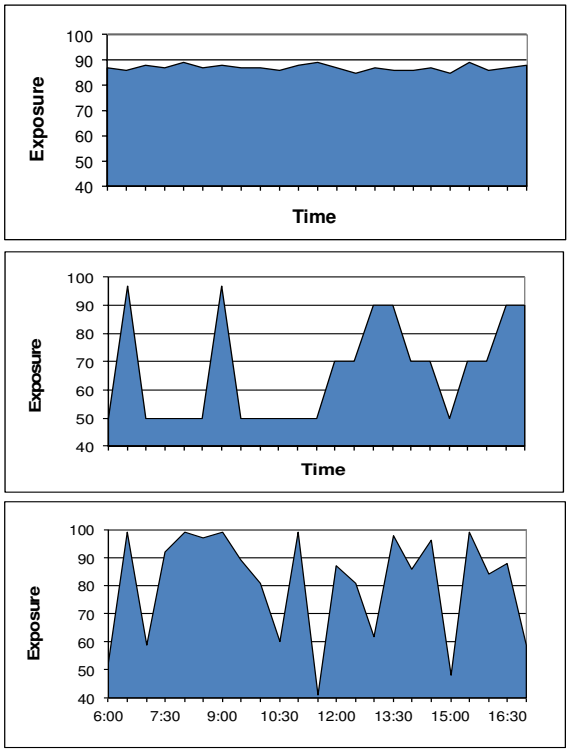
Noise map: modeled conditions, dBA



https://www.nps.gov/subjects/sound/soundmap.htm

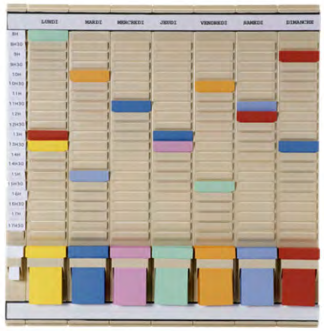
Noise maps are great. But they will never be enough

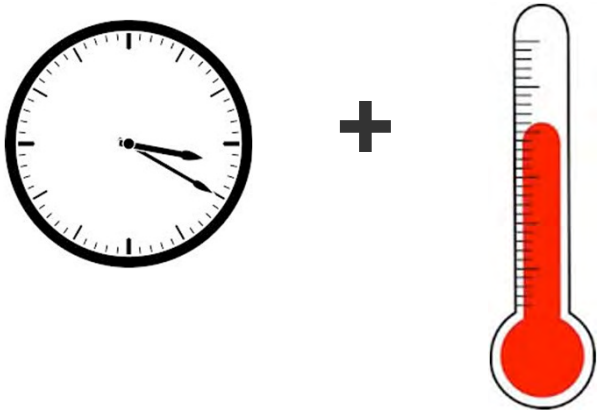
- Do not account for variations in behavior, activities
- Do not estimate personal exposures
- Often do not account for temporal variability
- Questionable assumptions, validation?



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)

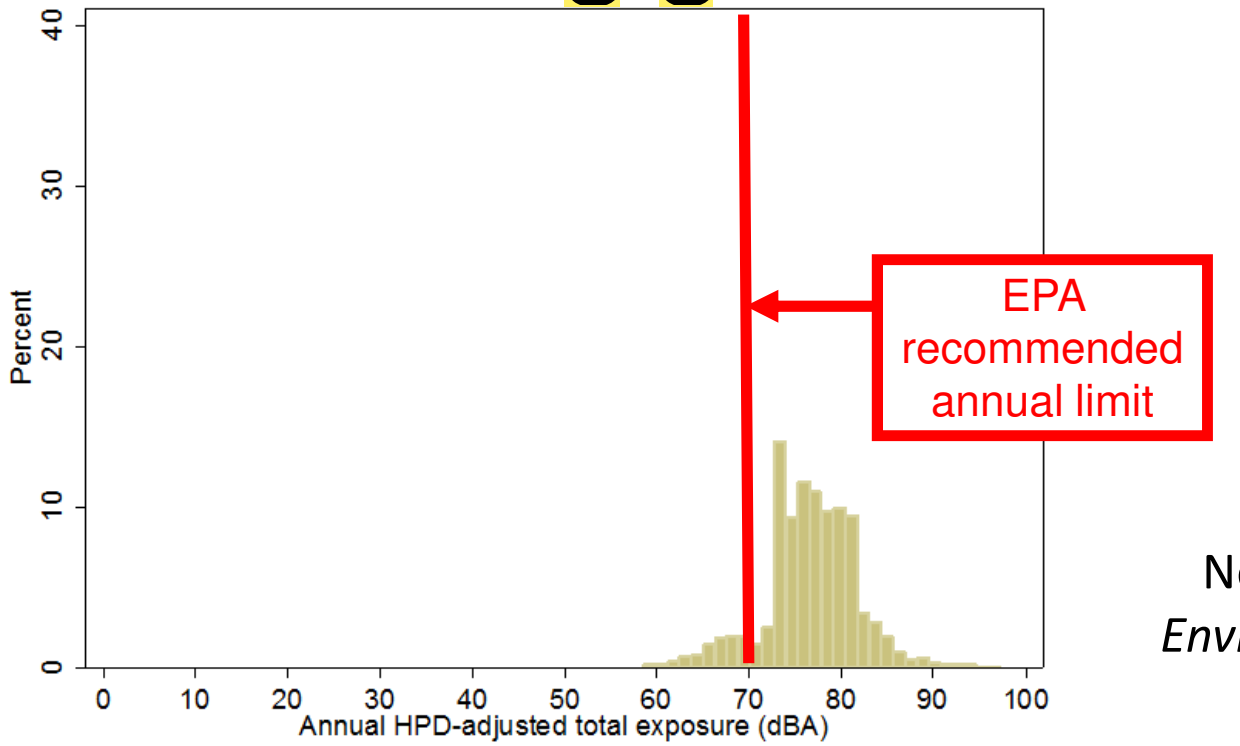




- Without information about all three, cannot estimate health risk

Personal monitoring gets us all three

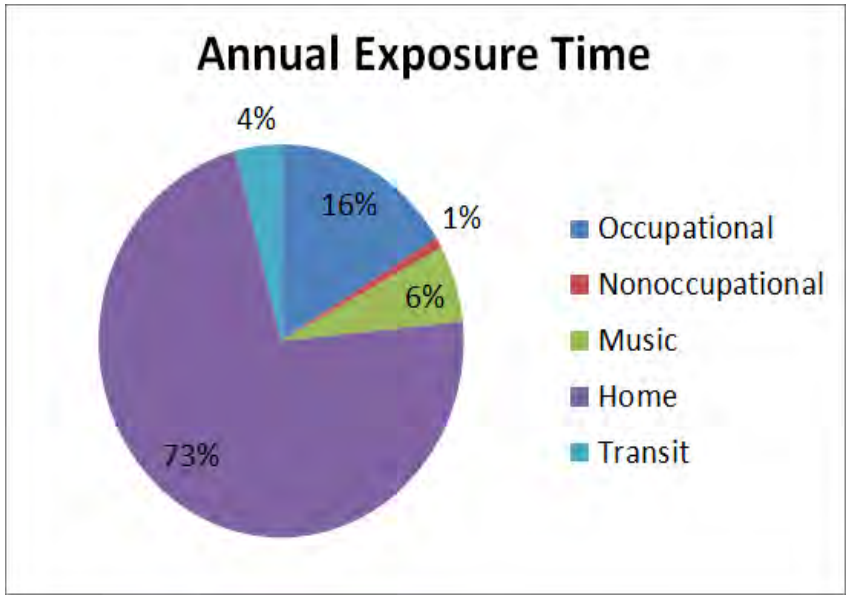
91% of 4436 NYC subjects > EPA limit from all noise sources combined and at risk of NIHL; mean 76.8 dBA

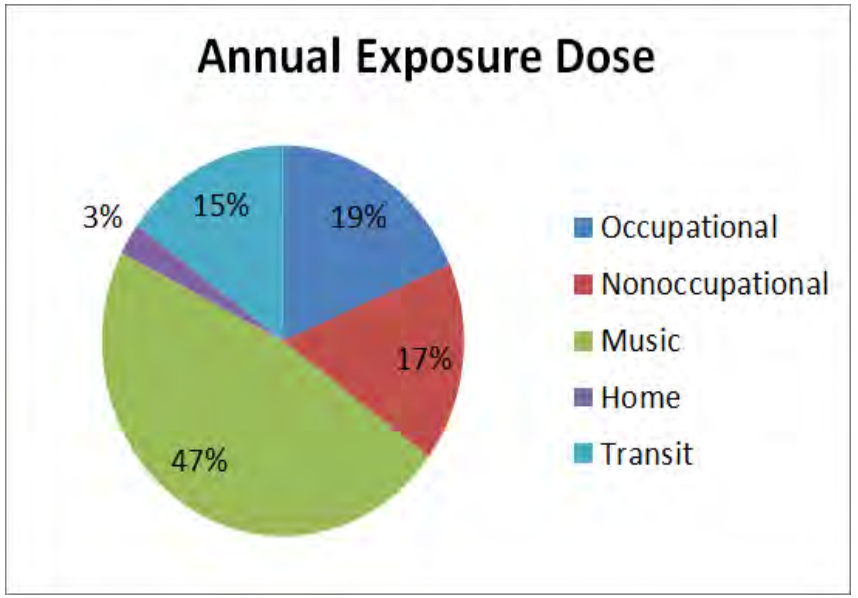


Neitzel et al, *Environ Sci Tech*, 2011

Noise maps would suggest exposures of 55-80 dBA

What personal monitoring shows





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

Neitzel et al, *Environ Sci Tech*, 2011

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

Commentary

Environmental Noise Pollution in the United States: Developing an Effective Public Health Response

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Background: Tens of millions of Americans suffer from a range of adverse health outcomes due to noise exposure, including heart disease and hearing loss. Reducing environmental noise pollution is achievable and consistent with national prevention goals, yet there is no national plan to reduce environmental noise pollution.

Objectives: We aimed to describe some of the most serious health effects associated with noise, summarize exposures from several highly prevalent noise sources based on published estimates as well as extrapolations made using these estimates, and lay out proven mechanisms and strategies to reduce noise by incorporating scientific insight and technological innovations into existing public health infrastructure.

Discussion: We estimated that 104 million individuals had annual $L_{AEQ,24h}$ levels > 70 dBA (equivalent to a continuous average exposure level of >70 dBA over 24 hr) in 2013 and were at risk of noise-induced hearing loss. Tens of millions more may be at risk of heart disease, and other noise-related health effects. Direct regulation, altering the informational environment, and altering the built environment are the least costly, most logistically feasible, and most effective noise reduction interventions.

Conclusion: Significant public health benefit can be achieved by integrating interventions that reduce environmental noise levels and exposures into the federal public health agenda.

Citation: Hammer MS, Swinburn TK, Neitzel RL. 2014. Environmental noise pollution in the United States: developing an effective public health response. Environ Health Perspect 122:115–119; http://dx.doi.org/10.1289/ehp.1307272

Introduction

Noise, or unwanted sound, is one of the most common environmental exposures in the United States (García 2001). In 1981, the U.S. Environmental Protection Agency (EPA) estimated that nearly 100 million people in the United States (about 50% of the population) had annual exposures to traffic noise that were high enough to be harmful to health (Simpson and Bruce 1981). However, despite the widespread prevalence of exposure, noise has historically been treated differently than pollutants of a chemical or radiological nature, and especially air pollution. Congress has not seriously discussed environmental noise in > 30 years, although noise exposure is a large public concern. For example, in New York City noise is consistently the number one quality of life issue, and authorities there received > 40,000 noise complaints in 2012 (Metcalfe 2013). Very few communities appear to consider the health risks of noise in their policy making (Network for Public Health Law 2013) despite the fact that the health effects of noise have been explored over many decades, and the body of evidence linking noise to various health effects is, therefore, more extensive than for most other environmental hazards (Goines and Hagler 2007; Paschier-Vermeer and Paschier 2000).

Even when cities and counties do address noise in their planning efforts, the results are disappointing. The Health Impacts Project (HIP) provides guidance for policy makers to identify the health consequences of potential projects by making public a national sample of health impact assessments (HIP 2013). Dozens of recent health impact statements in the HIP database have incorporated noise, but none appeared to assess changes in sleep disturbance, learning, hypertension, or heart disease. Although HIP does not provide a complete picture of U.S. health impact assessments, it does indicate that decision makers lack the information they need to protect communities from noise-related health effects. Environmental impact statements that calculate changes in noise levels also do not necessarily provide information about adverse health impacts resulting from these changes (U.S. Department of Transportation, Federal Highway Administration/Michigan Department of Transportation 2008).

In this commentary, we examine scientific and policy aspects of noise exposure. We first provide an overview of the relationship between high-impact health effects and noise. We then describe the most prevalent sources of noise and estimate prevalence of exposure. Finally, we explore policy approaches that can reduce the harmful effects of noise.

Chronic Noise: A Biopsychosocial Model of Disease

Chronic environmental noise causes a wide variety of adverse health effects, including sleep disturbance, annoyance, noise-induced hearing loss (NIHL), cardiovascular disease, endocrine effects, and increased incidence of diabetes (Paschier-Vermeer and Paschier 2000; Sørensen et al. 2013). This commentary is not intended to provide a comprehensive review of all noise-related health effects, which is available elsewhere (Goines and Hagler 2007). Rather, we focus on several highly prevalent health effects: sleep disruption and heart disease, stress, annoyance, and NIHL (Figure 1). It is important to note that the levels of noise exposures associated with these health effects range widely; as a result, the prevention of different health effects involves specification of different exposure limits and metrics.

Sleep and heart disease. People in noisy environments experience a subjective habituation to noise, but their cardiovascular system does not habituate (Muzet 2002) and still experiences activations of the sympathetic nervous system and changes from deep sleep to a lighter stage of sleep in response to noise. The body's initial startle response to noise is activation of the sympathetic (fight or flight) part of the nervous system, similar to the preparations the body makes just before waking in the morning. Although blood pressure normally drops during sleep, people experiencing sleep fragmentation from noise have difficulty achieving a nadir for any length of time because blood pressure rises with noise transients and heart rate increases with noise level (Haralabidis et al. 2008). Decreased quality and quantity of sleep elevates cardiovascular strain, which manifests as increased blood pressure and disruptions in cardiovascular circadian rhythms (Sforza et al. 2004).

Disordered sleep is associated with increased levels of stress hormones (Joo et al.

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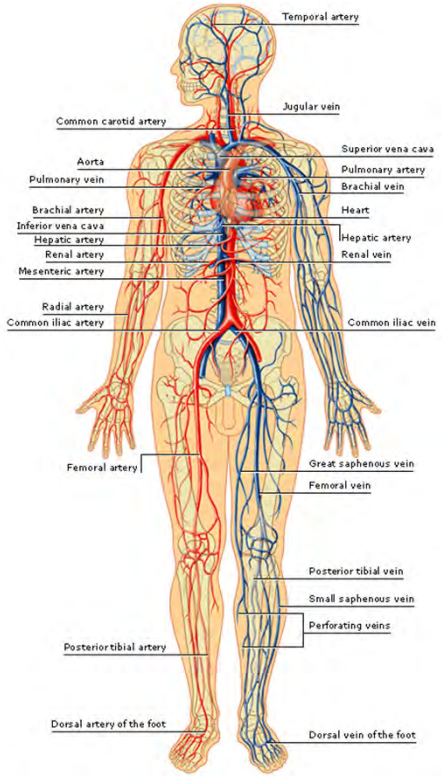
Hammer et al, *Environ Health Persp*, 2014

Health effects of environmental noise

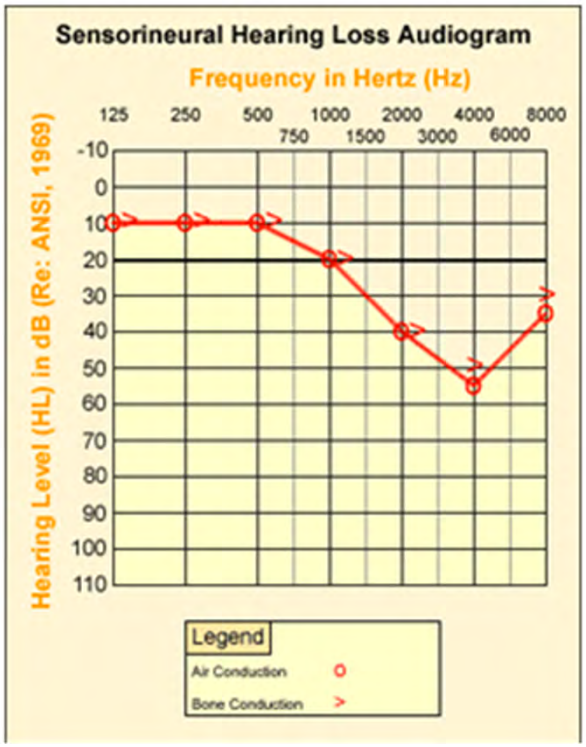
- Noise-induced hearing loss (duh)
- Cardiovascular disease (ischemic heart disease, hypertension)
- Injuries?
- Diabetes and/or endocrine disruption?
- Psychological/mental health effects?
- Cognitive effects?



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

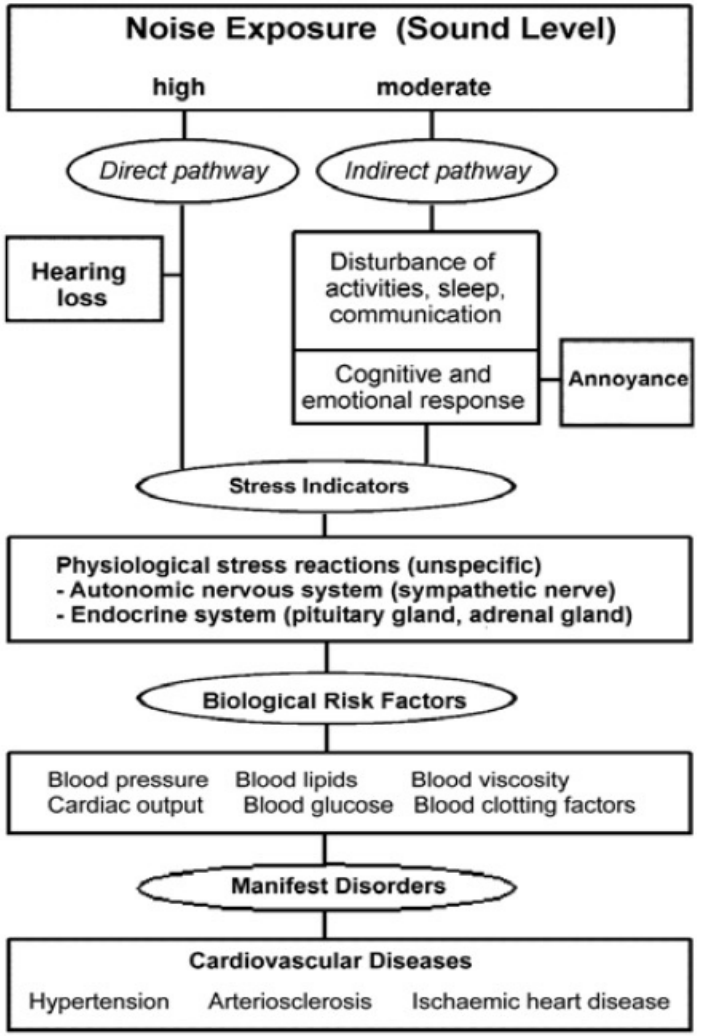


www.osha.gov/dts/osta/otm/new_noise/

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

Noise and cardiovascular disease



Babisch W, *Noise Health*, 2004

Evidence for noise → 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

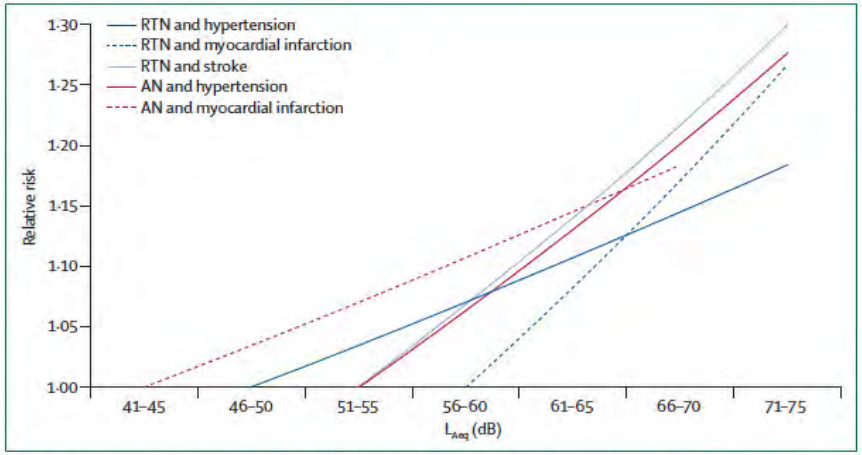


Figure 3: **Exposure–response curves of road and aircraft noise and cardiovascular endpoints**
RTN and hypertension (24 studies, noise indicator L_{Aeq16h}); RTN and myocardial infarction (five studies, noise indicator L_{Aeq16h}); RTN and stroke (one study, noise indicator L_{DEN}); AN and hypertension (five studies, noise indicator L_{DN}); and AN and MI (one study, noise indicator L_{DN}). RTN=road traffic noise. AN=aircraft noise.

Basner et al, *Lancet*, 2014

CVD from noise impacts in US

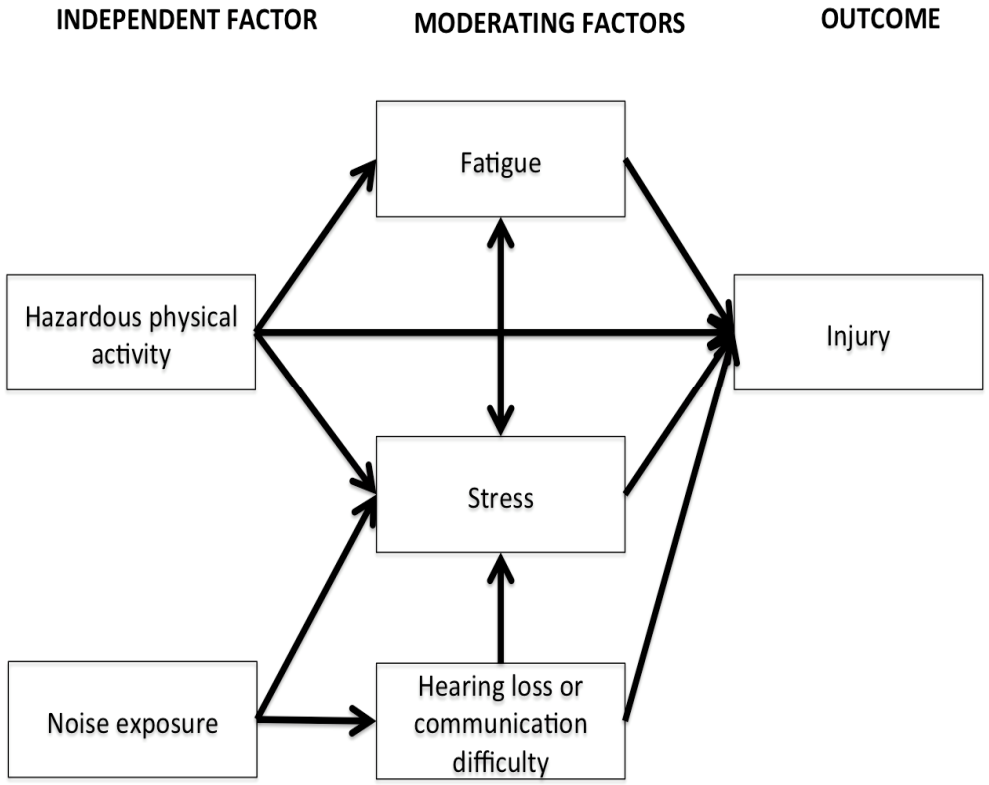
- Estimated CVD savings from 5 dB reduction in US population noise in 2014: $3.9 billion

Table 3. Model Results

Model	Current situation	5-dB reduction scenario estimate	Difference (current – reduction scenario)
Model 1: coronary heart disease			
Number of people exposed ≥55 dBA L_{DN}	145.5 million	0	-145.5 million
Number of affected individuals	15.4 million	15.1 million	-279,000
Population risk (%)	4.89	4.80	-0.09
Annual cost, direct ($)	96 billion	94.3 billion	-1.7 billion
Annual cost, indirect ($)	81.1 billion	79.6 billion	-1.5 billion
Model 2: hypertension			
Number of people exposed ≥ 55 dBA L_{DN}	145.5 million	0	-145.5 million
Number of affected individuals	77.9 million	76.7 million	-1.2 million
Population risk (%)	24.7	24.3	-0.4
Annual cost, direct ($)	47.5 billion	46.8 billion	-684 million
Annual cost, indirect ($)	3.5 billion	3.4 billion	-50 million

Swinburn et al, *Am J Prev Med*, 2015

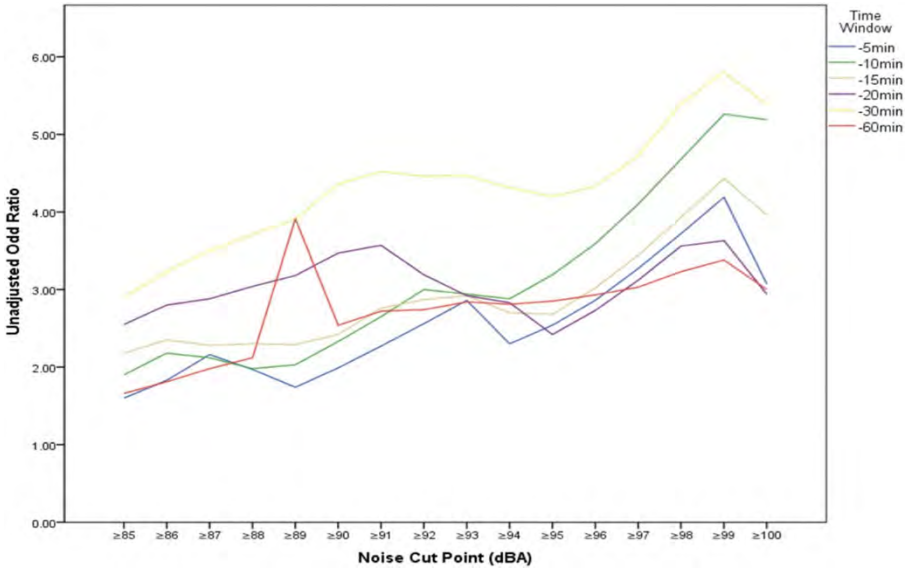
Noise and injuries



Neitzel, manuscript in preparation

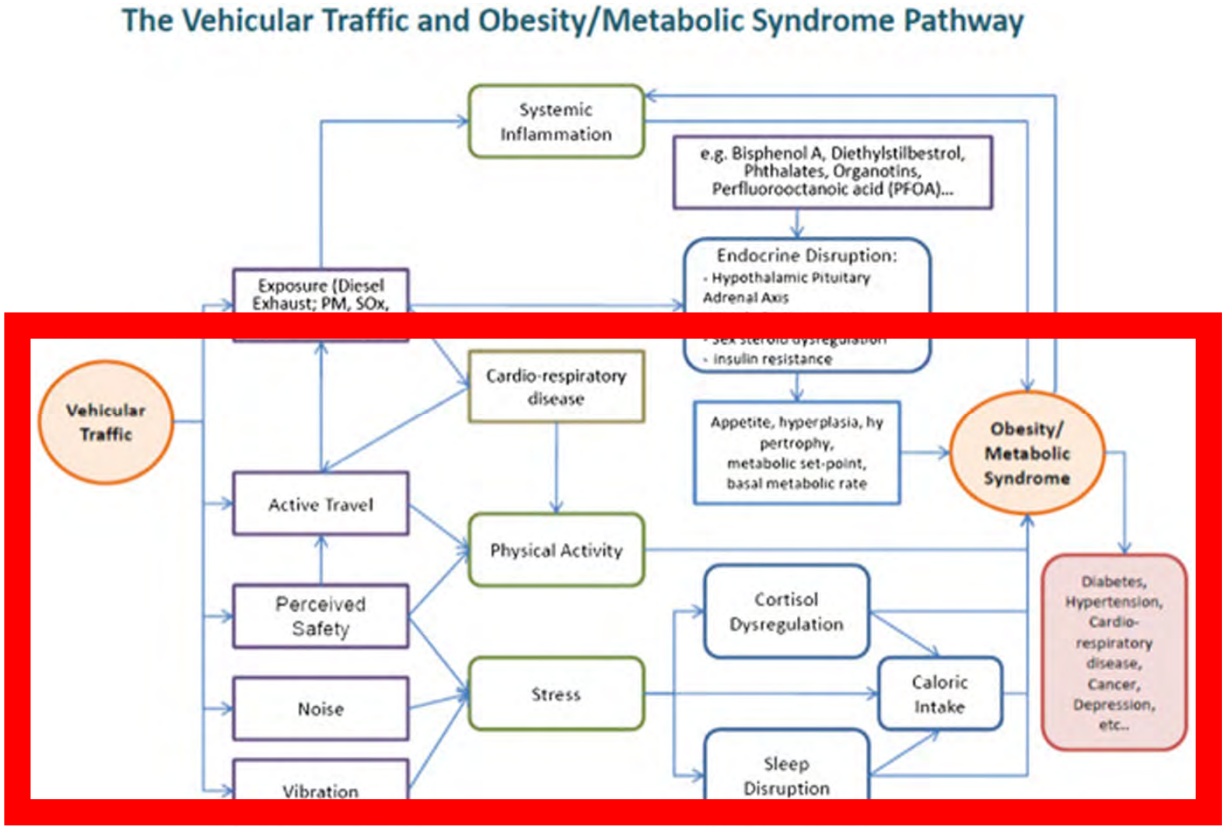
Evidence for noise → injuries

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



Neitzel et al, *Ann Occup Hyg*, 2016

Noise and diabetes



Jerrett et al, *Environ Health*, 2014

Noise and diabetes

- Few studies, many ecological study design
  - Long-term and short-term road noise increased risk of diabetes mortality in men in Barcelona (Barcelo et al, *Environ Res*, 2016; Recio et al, *Environ Res*, 2016)
  - 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

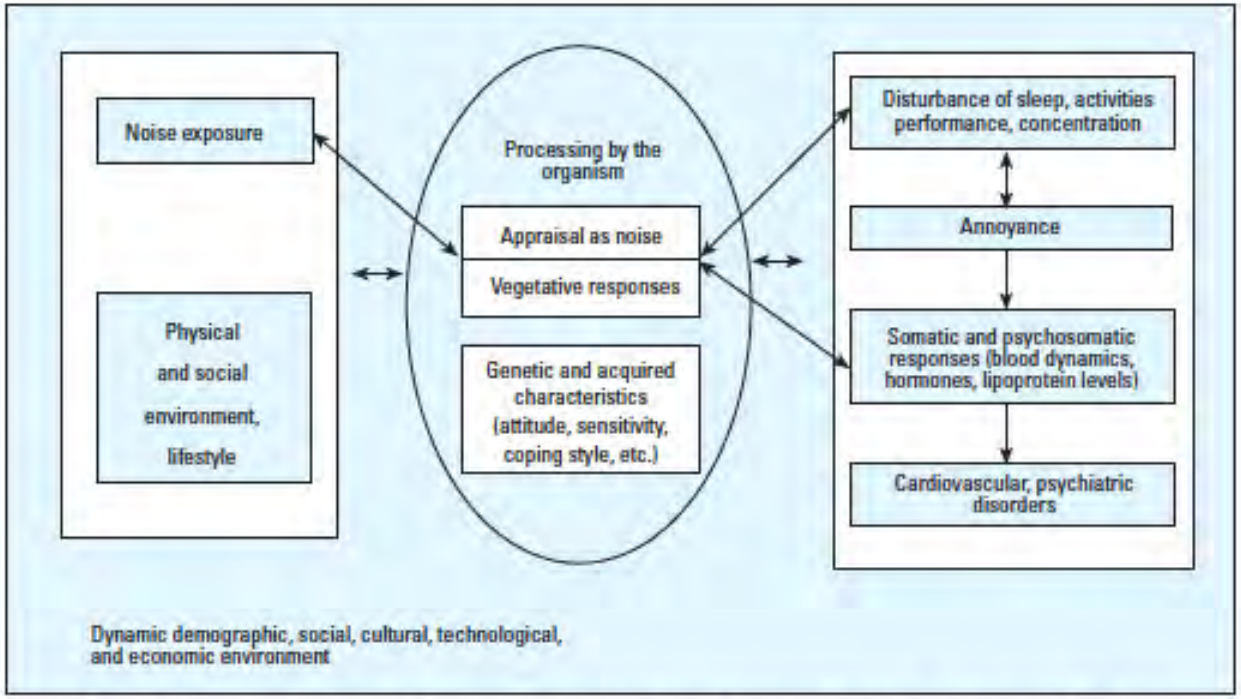


Figure 1. Conceptual model of the interaction of noise with humans and the occurrence of effects on health and quality of life (*2*).

Van Kempen et al, *Environ Health Persp*, 2002

Evidence for noise → 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

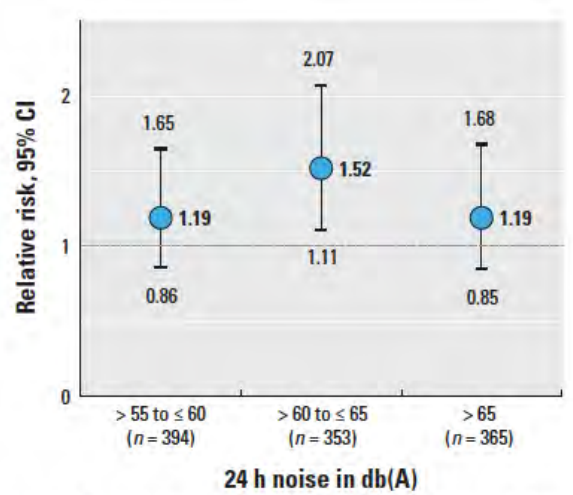
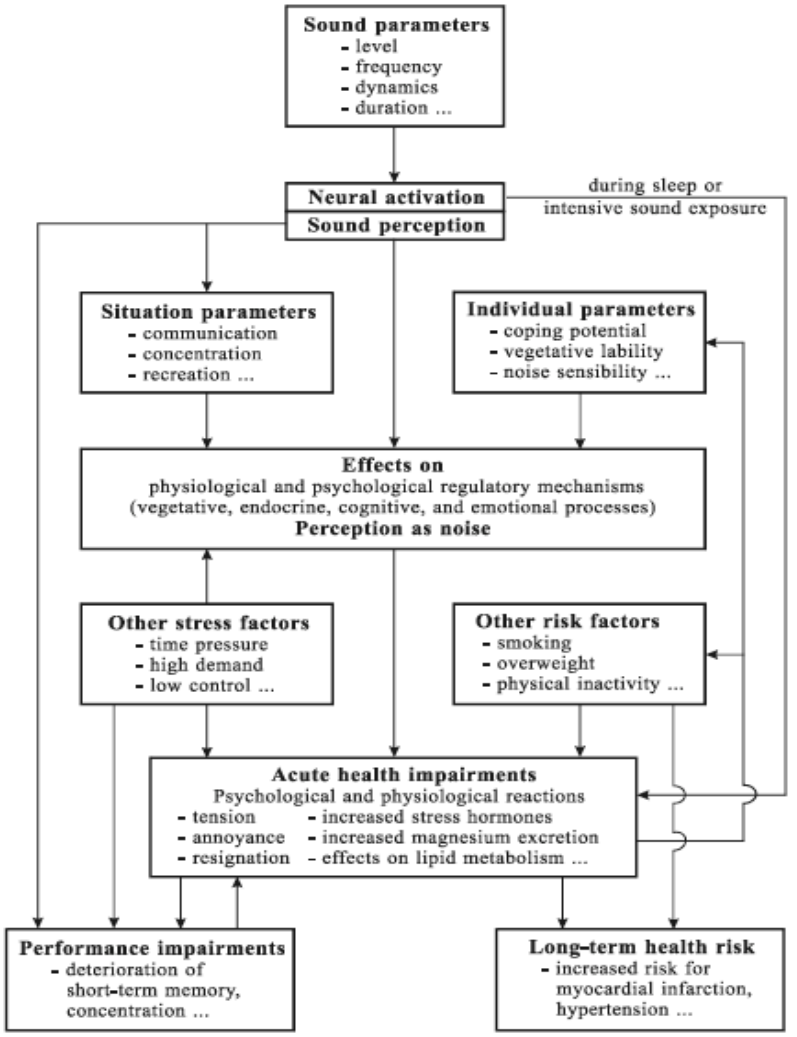


Figure 2. Relative risks and 95% confidence intervals of high depressive symptoms at follow-up in association with exposure to different categories of 24-hr noise compared with the lowest noise category [≤ 55 dB(A); *n* = 1,986], adjusted for baseline age, sex, education, income, economic activity, neighborhood-level socioeconomic status, and traffic proximity (Model 1). dB(A), A-weighted decibels.

Orban et al, *Environ Health Persp*, 2016

Noise and cognitive effects



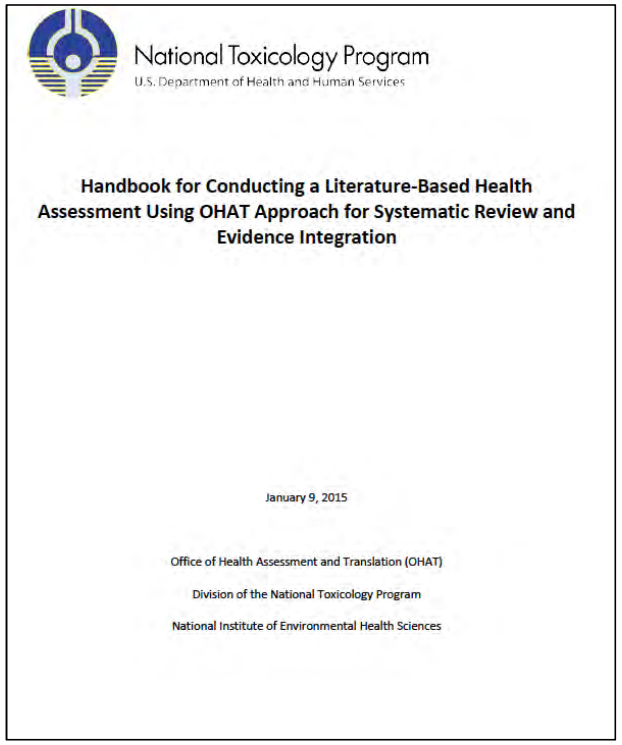
Ising et al, *Noise Health*, 2004

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


National Toxicology Program
U.S. Department of Health and Human Services

Handbook for Conducting a Literature-Based Health Assessment Using OHAT Approach for Systematic Review and Evidence Integration

January 9, 2015

Office of Health Assessment and Translation (OHAT)
Division of the National Toxicology Program
National Institute of Environmental Health Sciences

https://ntp.niehs.nih.gov/pubhealth/hat/review/index-2.html

"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

Table 4.1: Guideline values for community noise in specific environments.

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

WHO, 1999

*American Conference of Governmental Industrial Hygienists

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/