

# **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

CDC National Environmental Public Health Tracking

CDC Centers for Disease Control and Prevention  
CDC 24/7: Saving Lives. Protecting People.™

SEARCH

CDC A-Z INDEX ▾

## Environments

National Environmental Public Health Tracking > Environments

Environments

The most common environmental health hazards are air and water pollution.

Climate Change

- Climate Change and Health
- Tracking Climate Change
- Search Climate Change Data

Community Characteristics

- Community Characteristics and Health
- Tracking Community Characteristics
- Search Community Characteristics Data

Community Design

- Community Design and Health
- Tracking Community Design
- Search Community Design Data

Toxic Substance Releases

- Toxic Substances and Health
- Tracking Toxic Substance Releases
- Search Toxic Substance Releases Data

Outdoor Air

- Outdoor Air and Health
- Tracking Outdoor Air
- Search Outdoor Air Data

Water

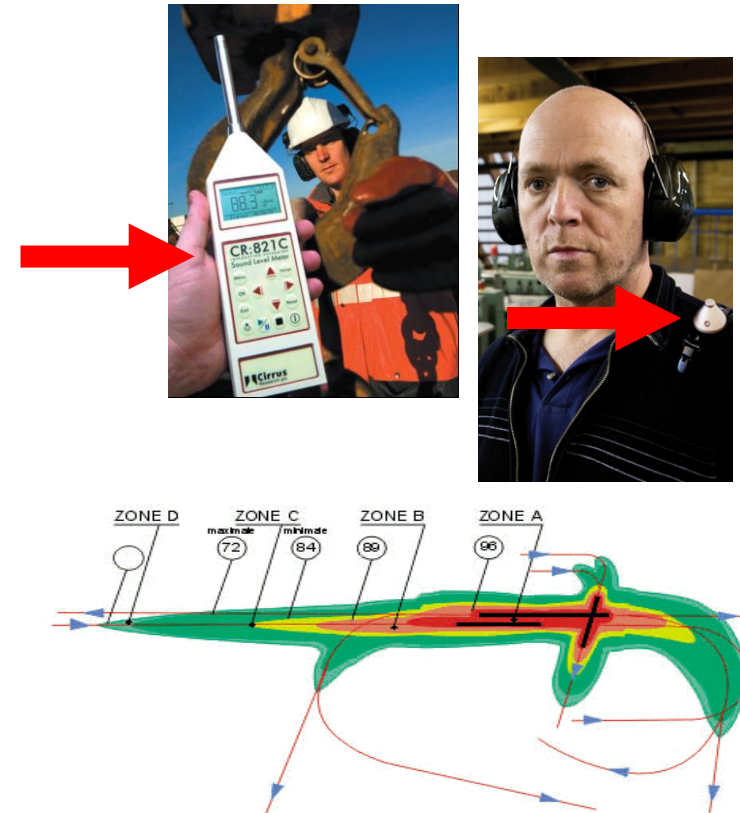
- Community Water
- Search Community Water Data

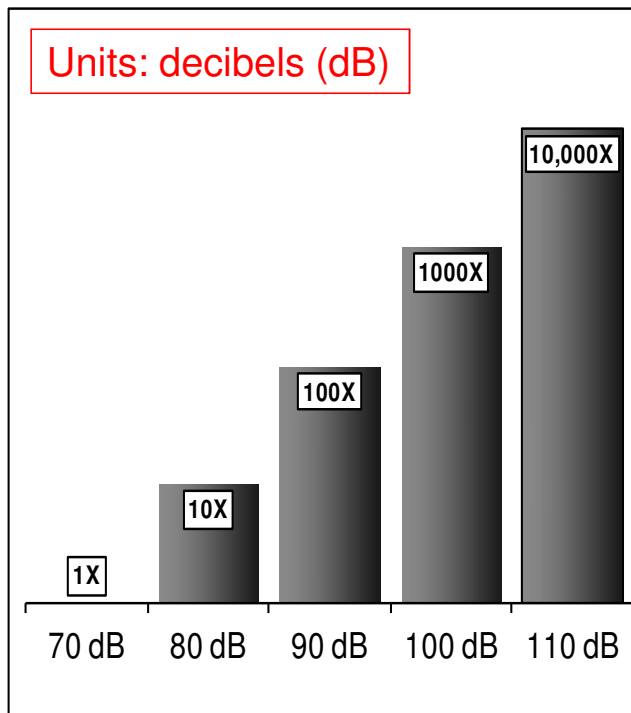
Noise?

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

# Noise exposure: measurements

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



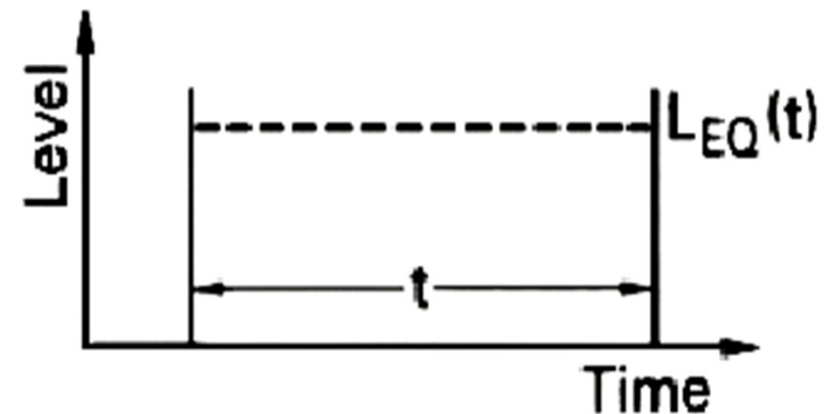
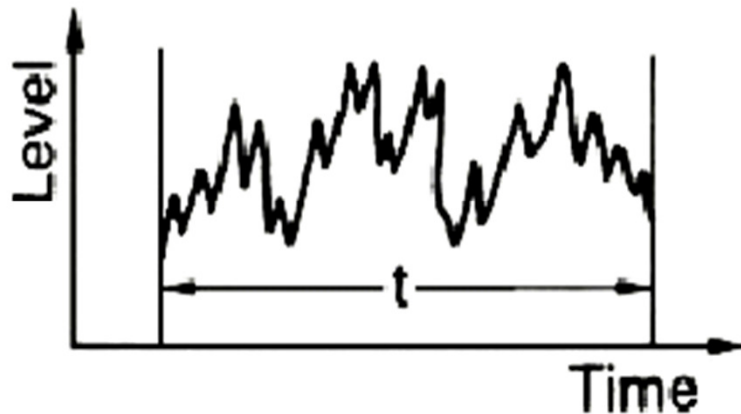


A-weighting typically used



# 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](https://www.fhwa.dot.gov/Environment/noise/regulations_and_guidance/analysis_and_abatement_guidance/fig1.gif)

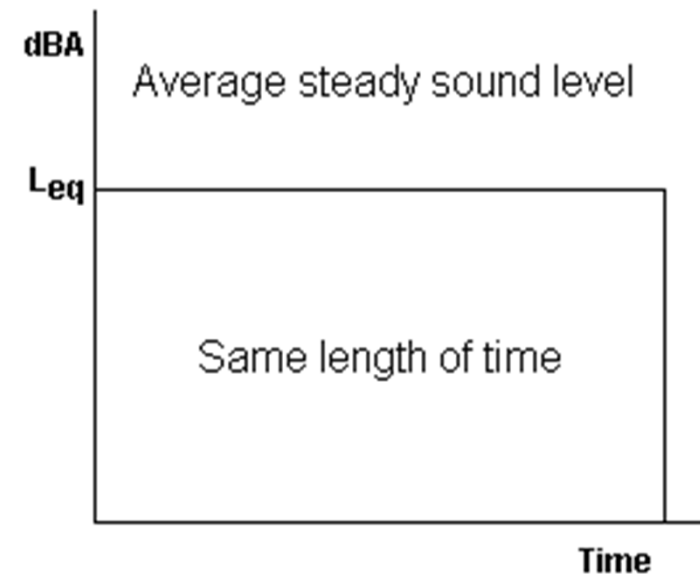
# Common environmental noise metrics

## 1. $L_{EQ}$

- Assumes all periods contribute equally to risk

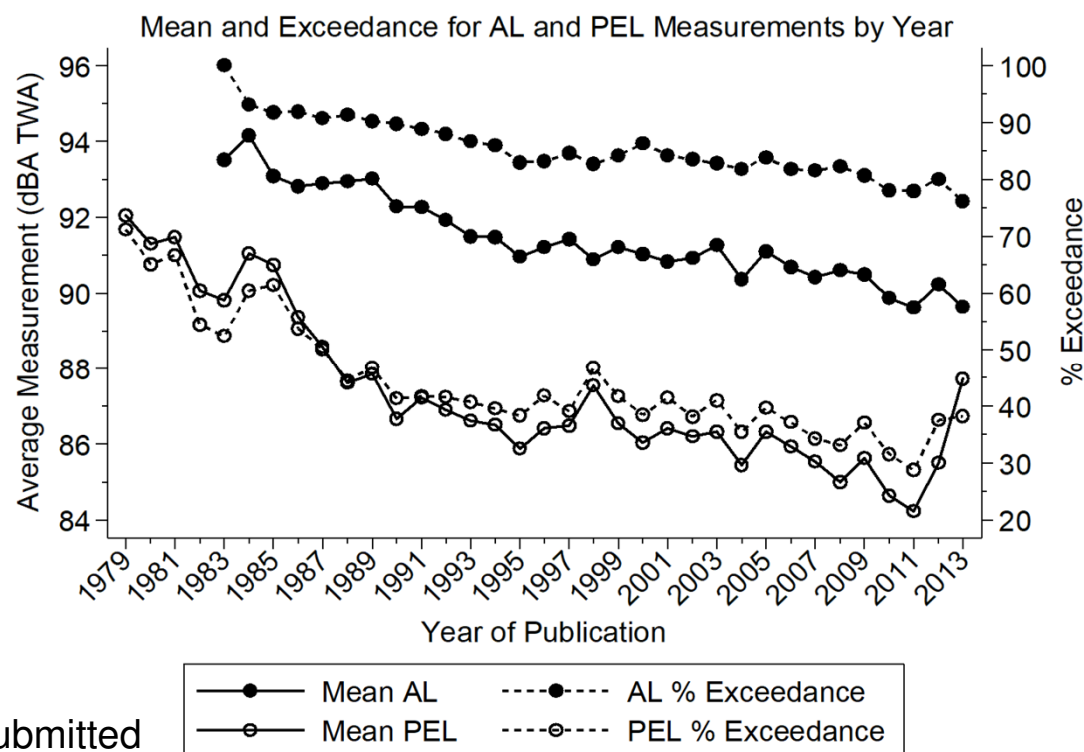
## 2. $L_{DN}$ (Day-Night Level)

- $L_{EQ}$  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?

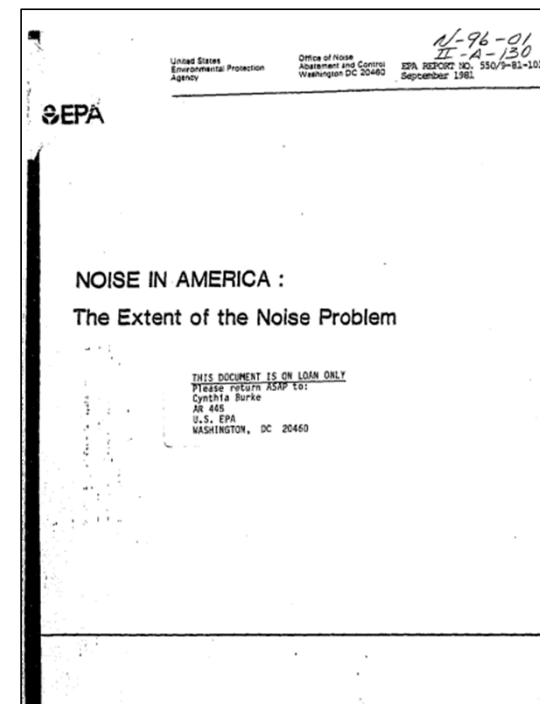
- Occupational Safety and Health Administration (OSHA) measurements
  - ~750,000 Permissible Exposure Limit (PEL)
  - ~320,000 Action Level (AL)



Sayler et al, manuscript submitted

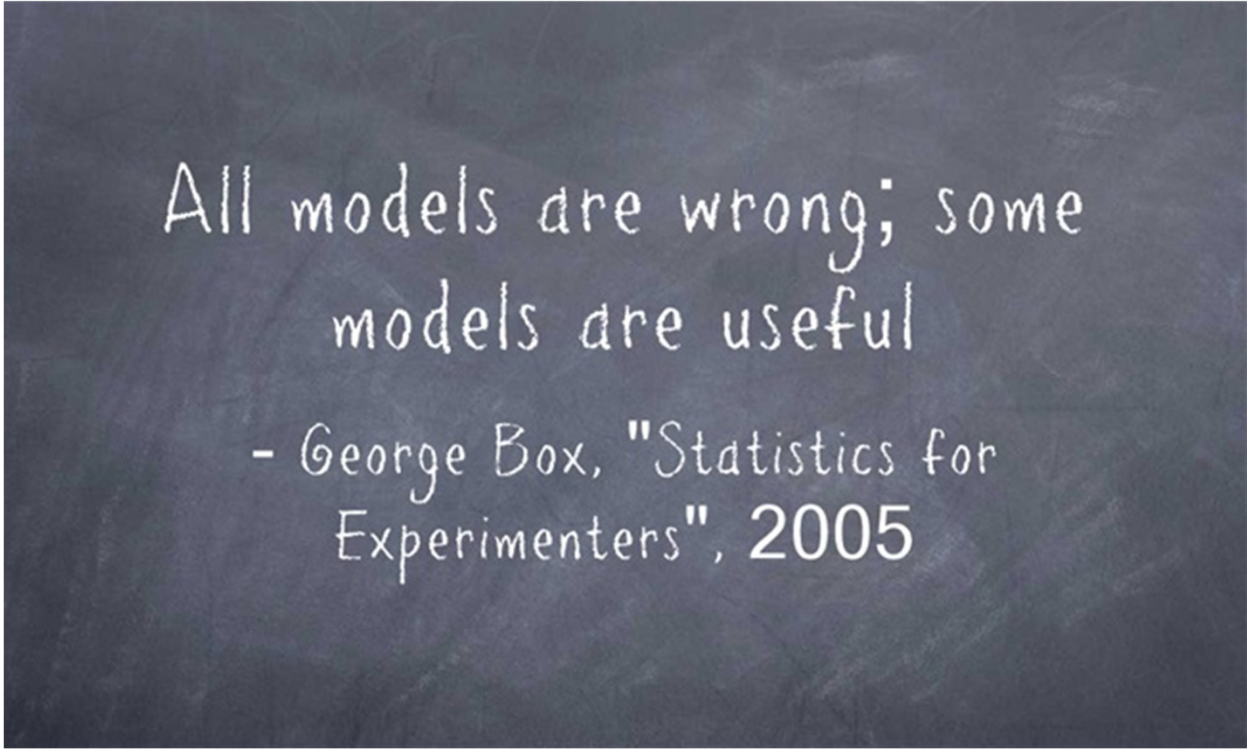
# What do we know about US environmental noise?

- 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

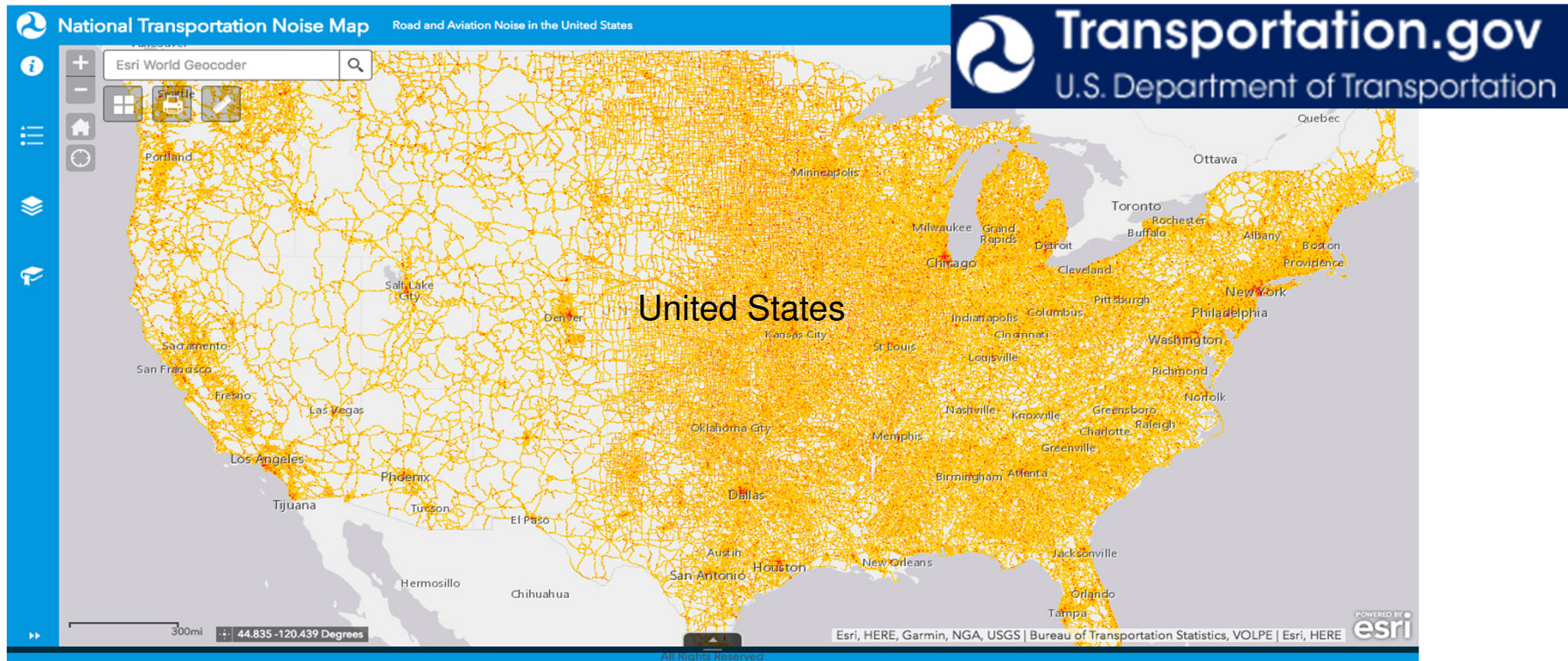
# Why differentiate modeling from measurements?



All models are wrong; some  
models are useful

- George Box, "Statistics for  
Experimenters", 2005

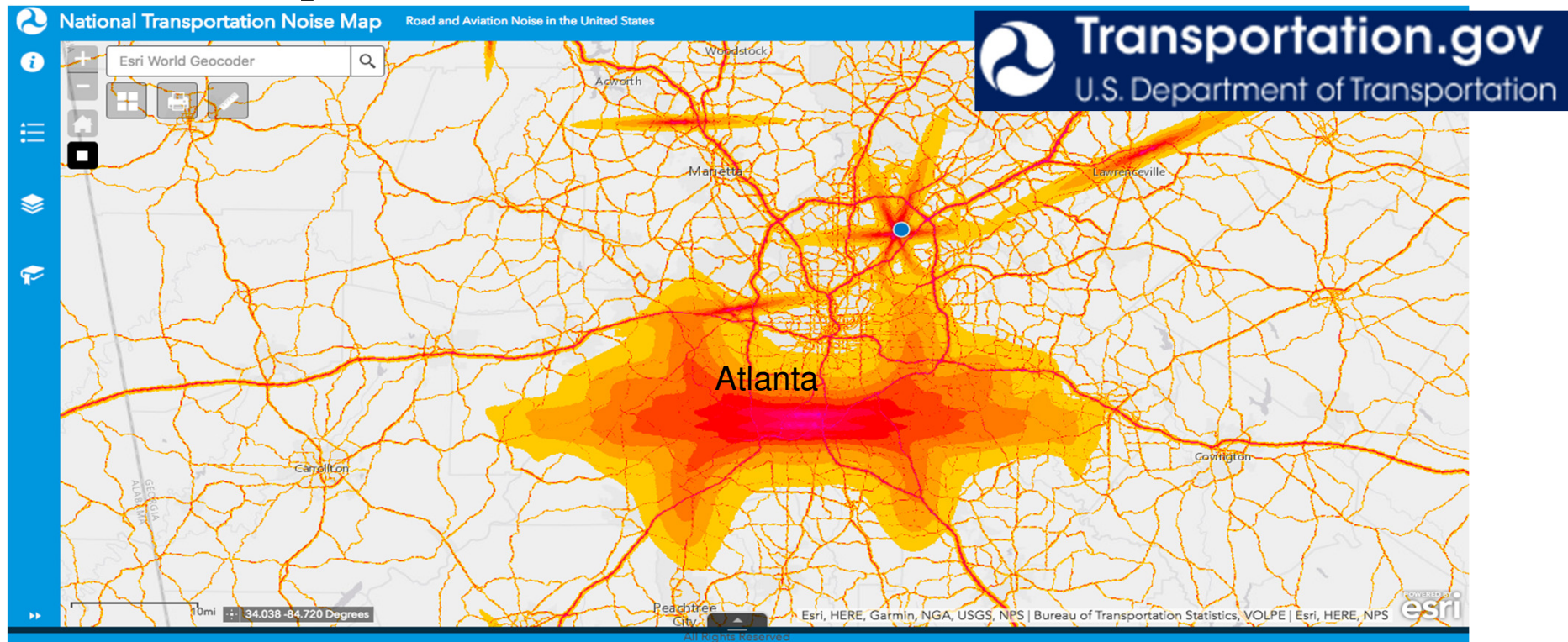
# Noise map: modeled road and air, dBA



<https://www.transportation.gov/highlights/national-transportation-noise-map>

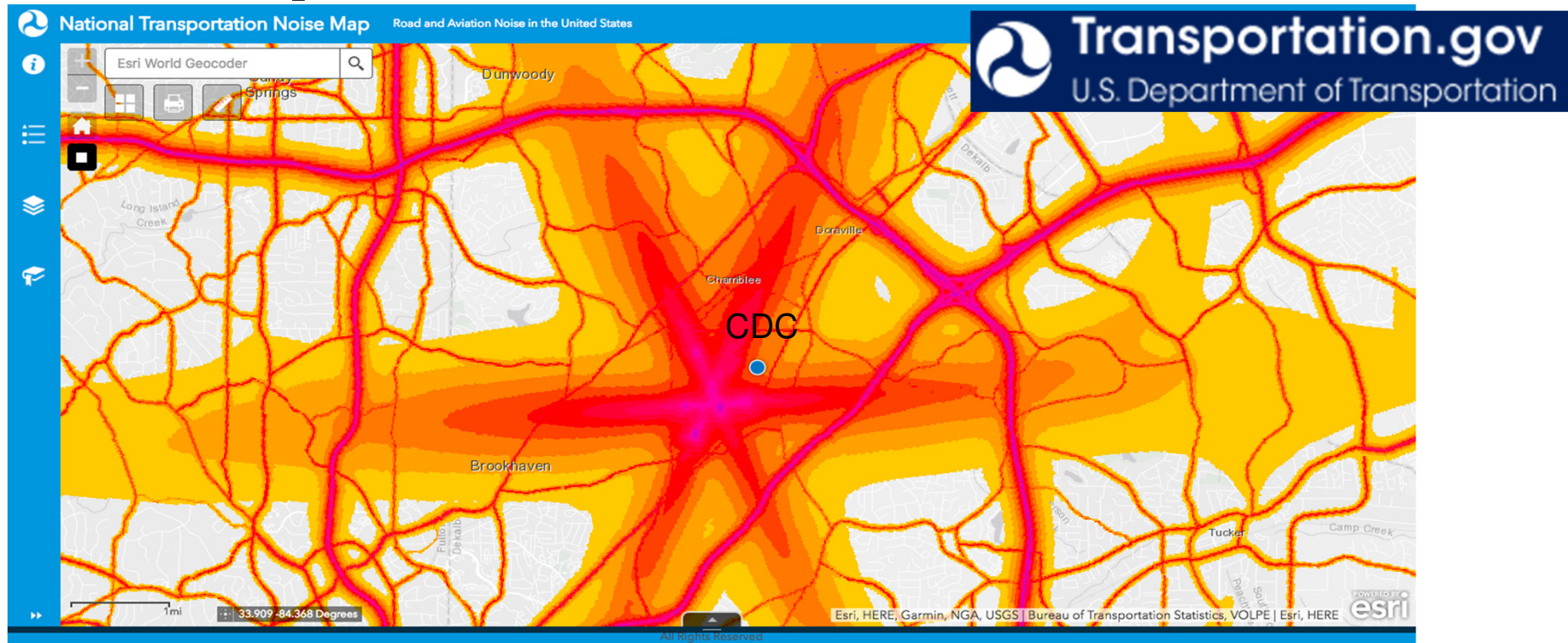


# Noise map: modeled road and air, dBA



<https://www.transportation.gov/highlights/national-transportation-noise-map>

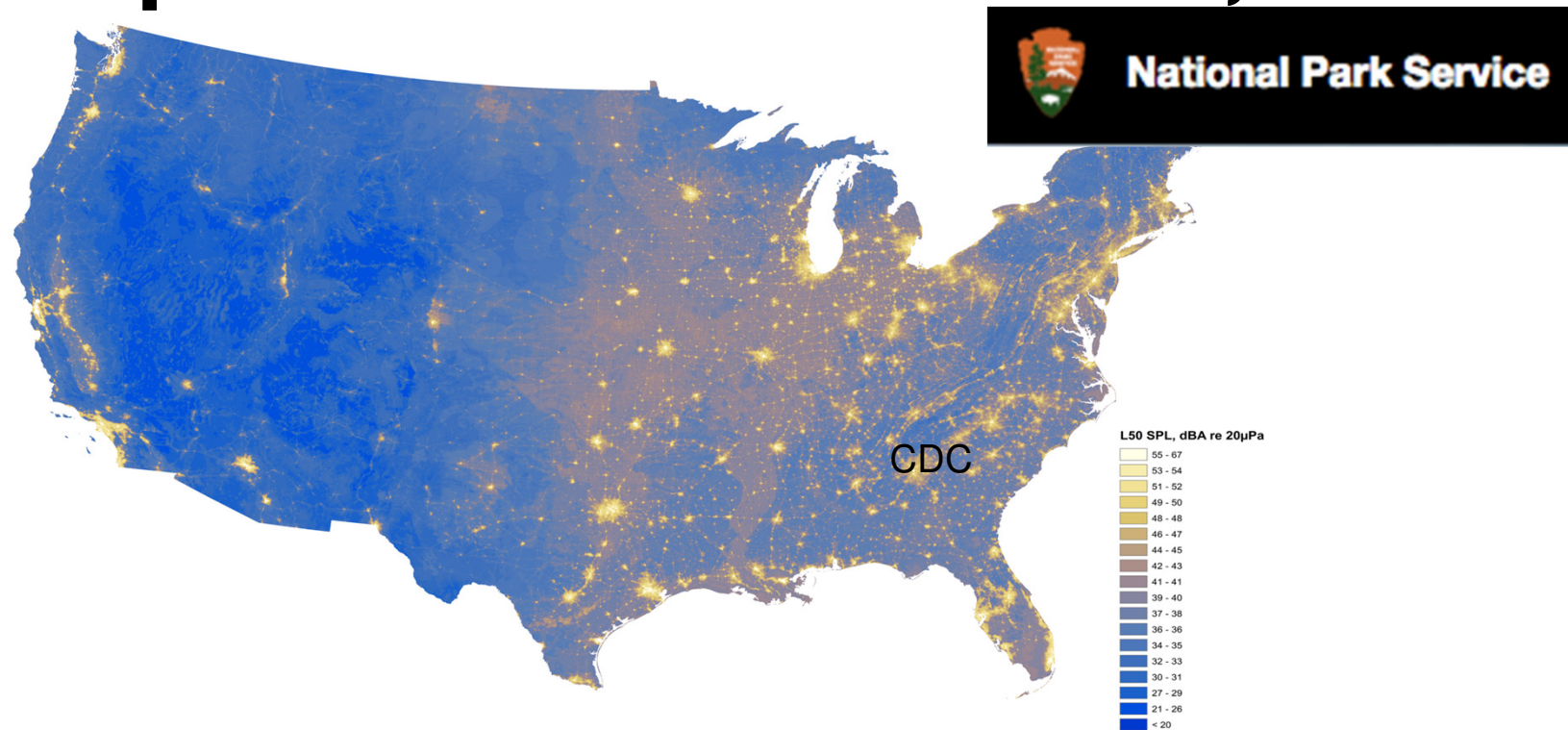
# Noise map: modeled road and air, dBA



<https://www.transportation.gov/highlights/national-transportation-noise-map>

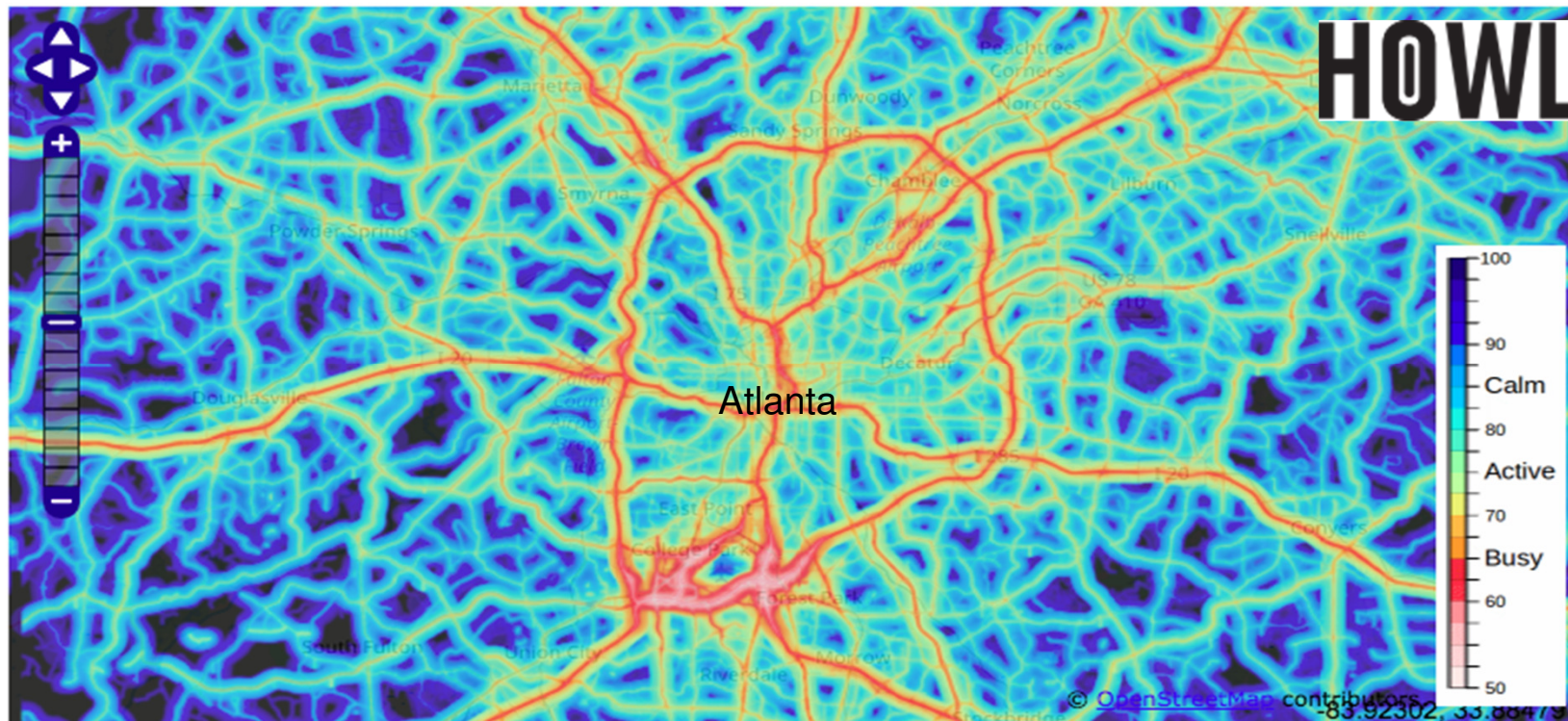


# Noise map: modeled conditions, dBA



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

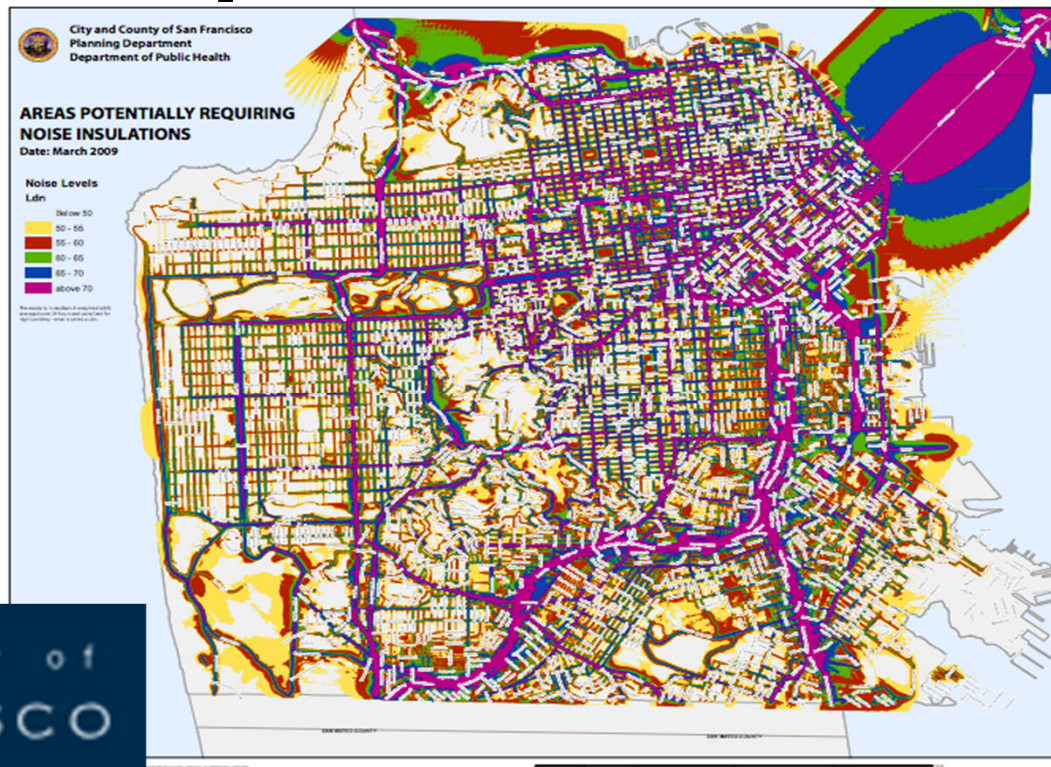
# Noise map: modeled...?



<http://howloud.com/>



# Noise map: modeled road, dBA

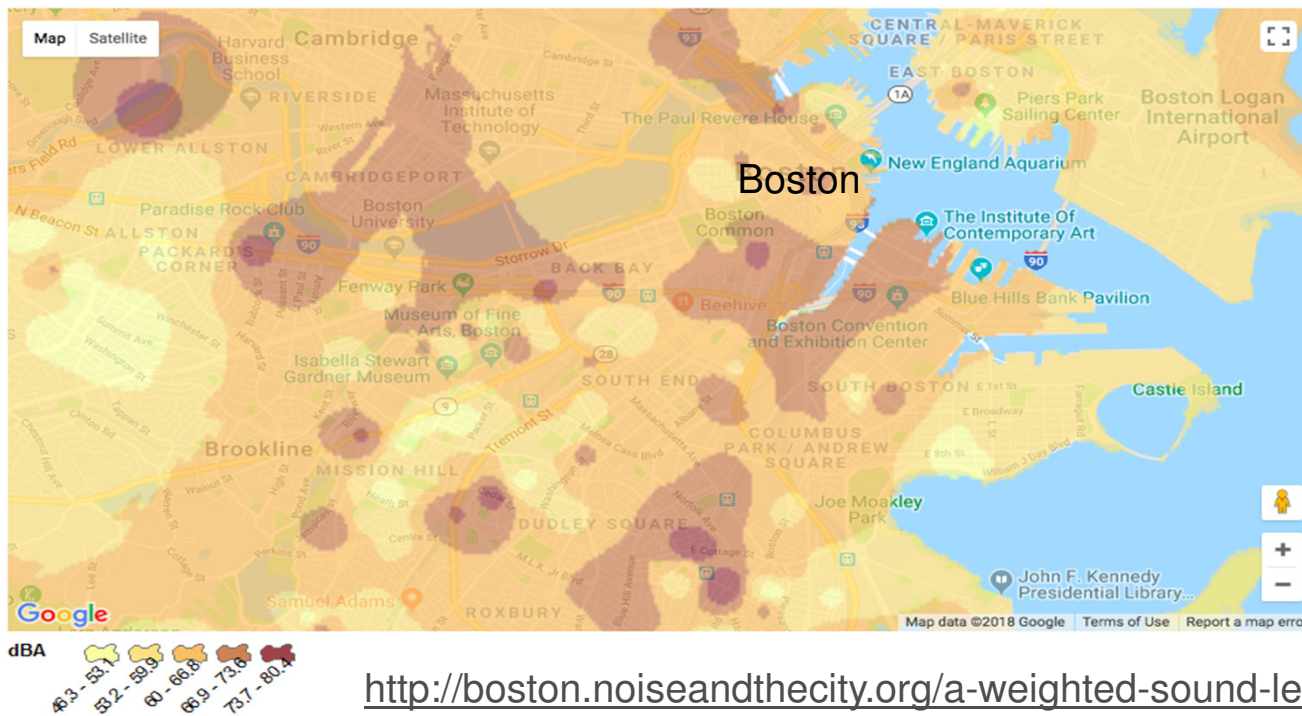


City and County of  
SAN FRANCISCO

<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

McAlexander et al. *Environ Health* 2015.

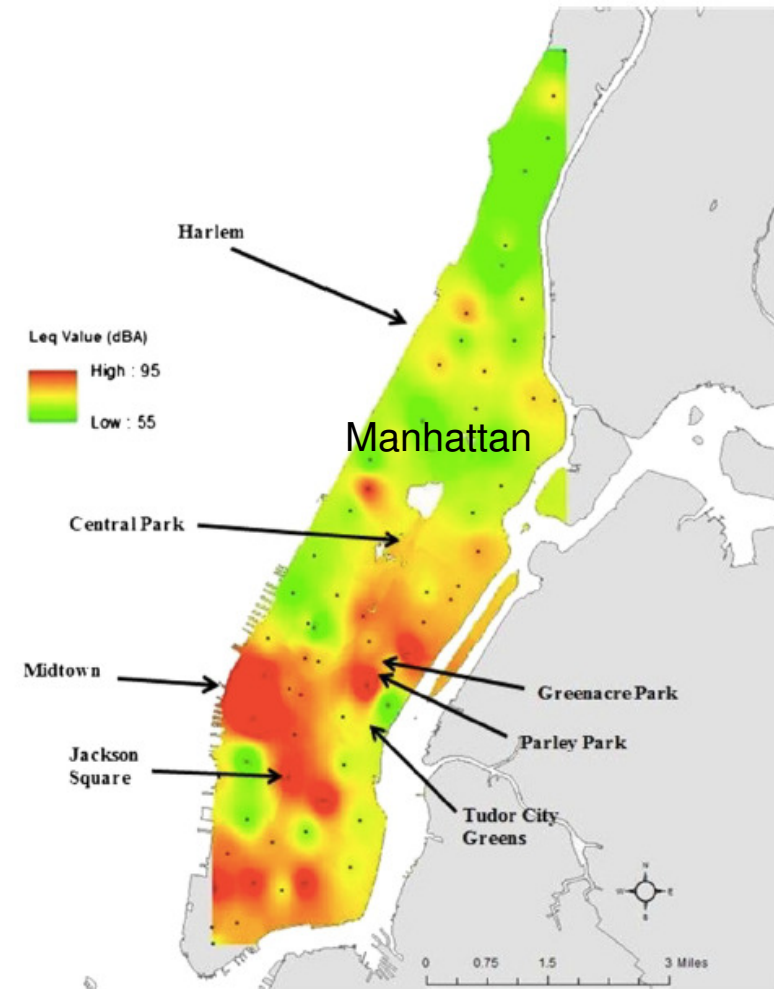
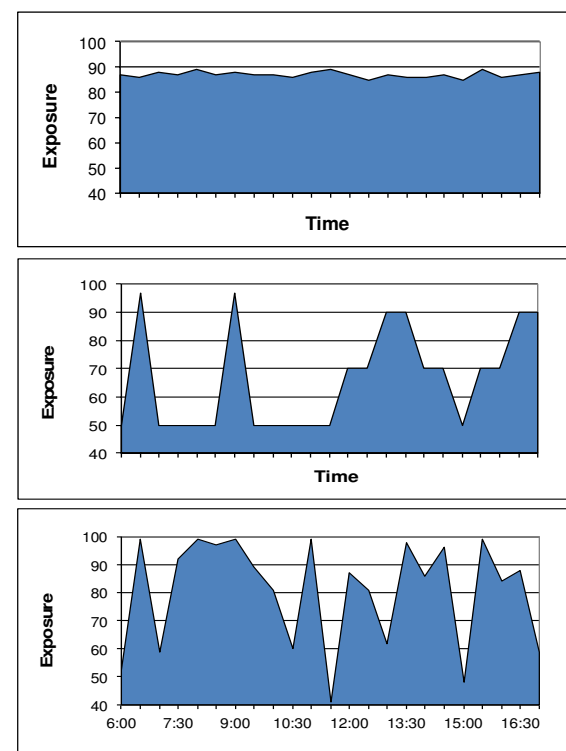


Figure 1 Estimated noise levels across Manhattan. Indicates measurement location.

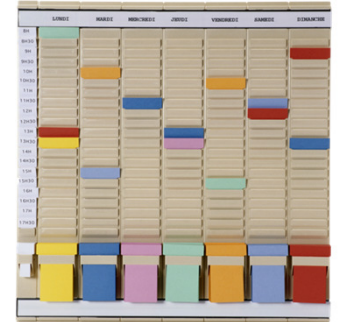
# Noise maps are great. But they will never be enough

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

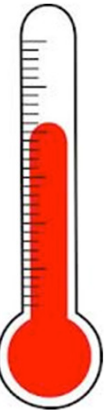


# If you remember nothing else today...

- 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

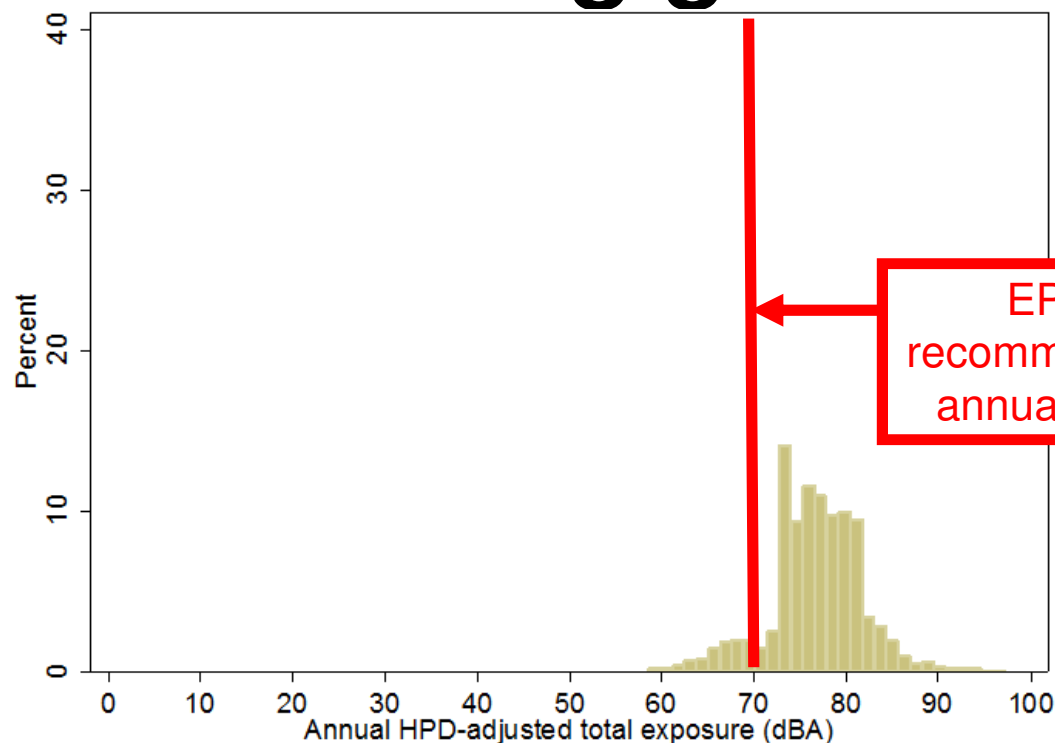


+



# 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**

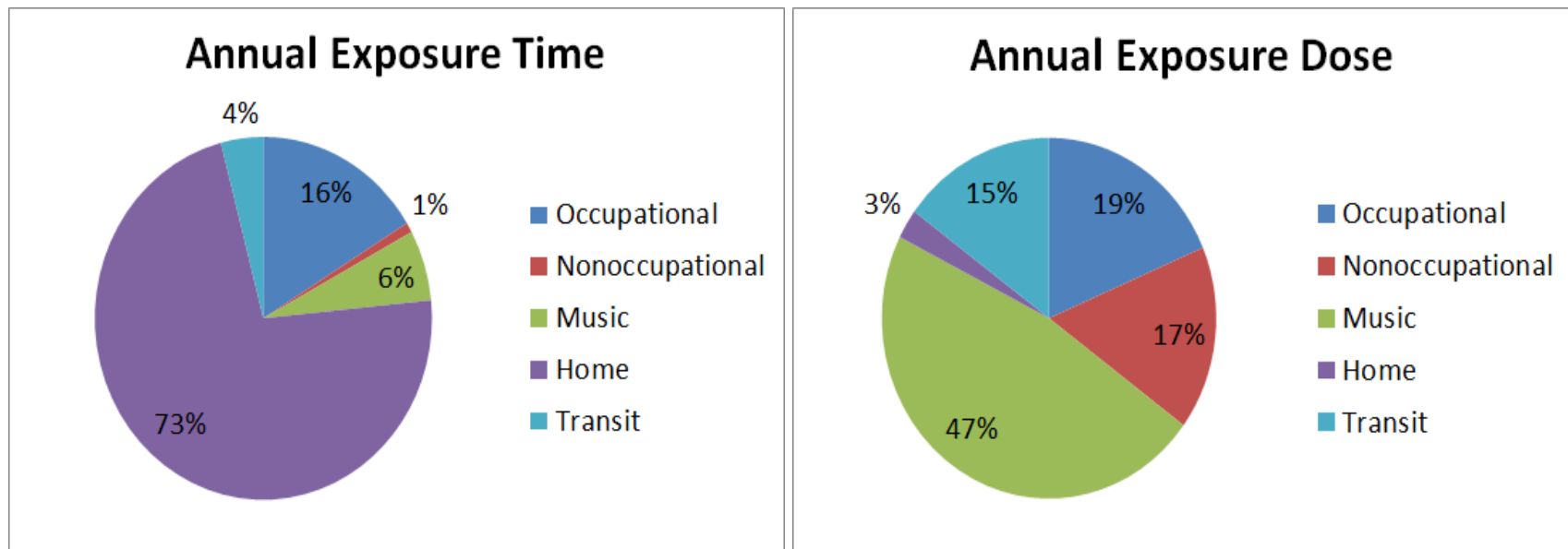


Neitzel et al,  
*Environ Sci Tech*,  
2011

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

All IHP content is accessible to individuals with disabilities. A fully accessible version of this article is available at <http://ehp1.ehponline.org/doi/10.1289/ehp.1307272>.

Commentary

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

Monica S. Hammer,<sup>1</sup> Tracy K. Swinburn,<sup>2</sup> and Richard L. Neitzel<sup>2,3</sup>

<sup>1</sup>The Network for Public Health Law—Mid-States Region, The University of Michigan School of Public Health, Ann Arbor, Michigan, USA; <sup>2</sup>The Risk Science Center, The University of Michigan, Ann Arbor, Michigan, USA; <sup>3</sup>The Department of Environmental Health Sciences, The University of Michigan, Ann Arbor, Michigan, USA

**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 infrastructures.

**DISCUSSION:** We estimated that 104 million individuals had annual Leq 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. Strict regulation, altering the informational environment, and altering the built environment are the least costly, most logistically feasible, and most effective noise reduction interventions.

**CONCLUSIONS:** Significant public health benefits 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 (Garcia 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 exposure to traffic noise that was 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; Paunicher-Yermore and Paunicher 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 (Paunicher-Yermore and Paunicher 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 acute response to noise is activation of the sympathetic (fight or flight) part of the nervous system, similar to the preparation 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. 2004). *Address correspondence to R.L. Neitzel, University of Michigan, Department of Environmental Health Sciences, 1415 Washington Heights, 6611 SPH1, Ann Arbor, MI 48109 USA. Telephone: (734) 763-2876. E-mail: neitzel@umich.edu*

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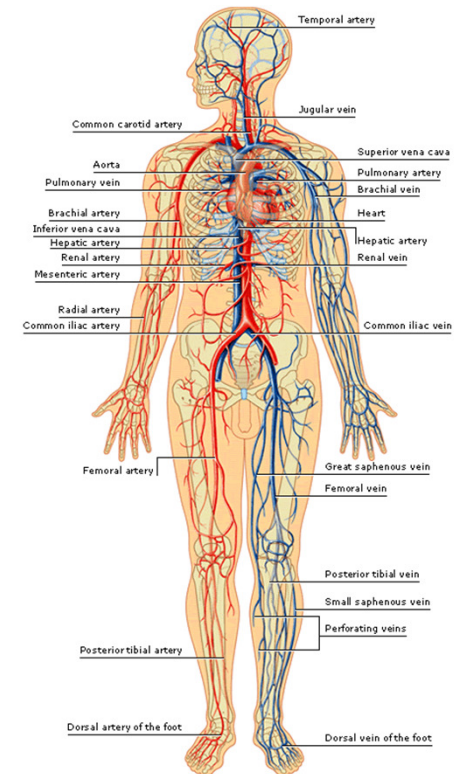
Environmental Health Perspectives • VOLUME 122 | NUMBER 2 | February 2014

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Hammer et al, *Environ Health Persp*, 2014

# Health effects of environmental noise

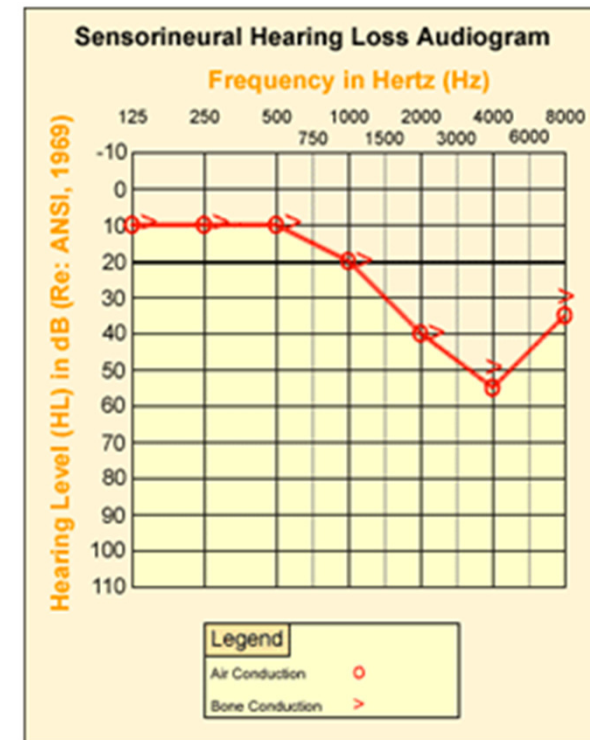
- Noise-induced hearing loss (duh)
- Cardiovascular disease (ischemic heart disease, hypertension)
- Injuries?
- Diabetes and/or endocrine disruption?
- Psychological/mental health effects?
- Cognitive effects?



<https://www.pinterest.com/pin/464081936578774649/>

# Noise-induced hearing loss (NIHL)

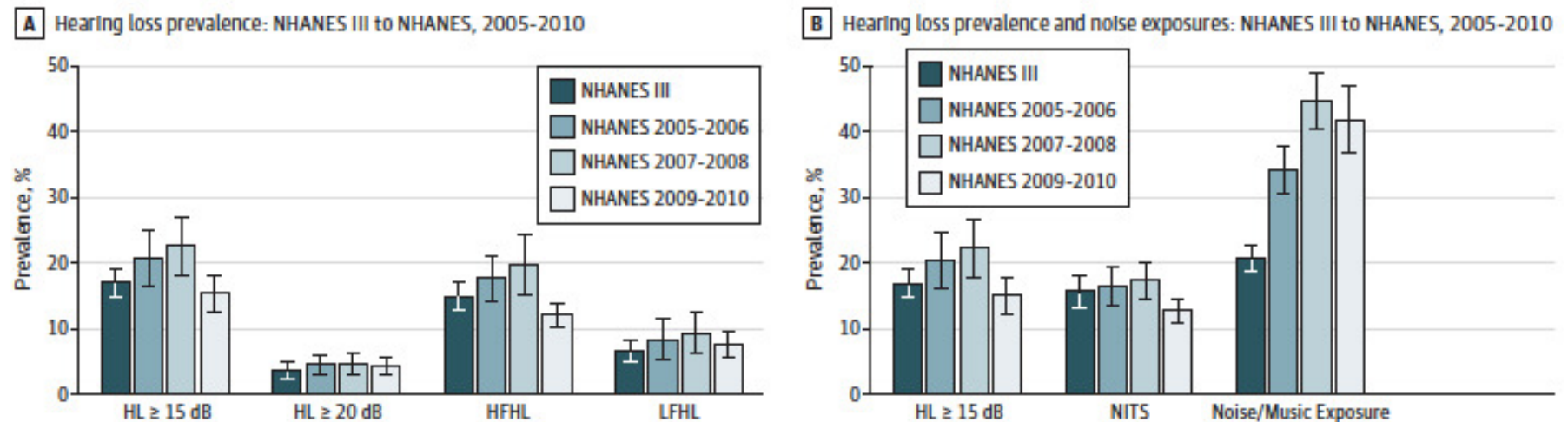
- Chronic exposures cause metabolic damage to cochlea, eventual cell death
  - Neuronal destruction possible → adequate detection, poor understanding
  - Well-understood dose-response; risk begins at 70 dBA  $L_{EQ}(24)$
- Mechanical damage (acoustic trauma)
- Tinnitus and hyperacusis



[www.osha.gov/dts/osta/otm/new\\_noise/](http://www.osha.gov/dts/osta/otm/new_noise/)

# NIHL in US children

Figure 1. Prevalence Estimates of Hearing Loss and Noise Exposures



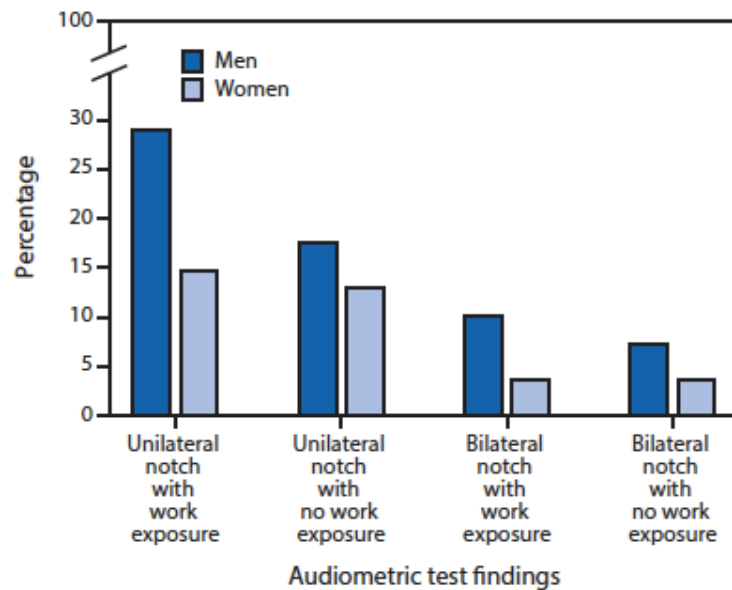
A, Prevalence estimates and 95% confidence intervals (error bars) for several common definitions of hearing loss, and (B) exposure to loud noise or music through headphones in the 24 hours prior to audiometry, compared with prevalence of hearing loss at or greater than 15 dBs. dB indicates decibels;

HFHL, high-frequency hearing loss; HL, hearing loss; LFHL, low-frequency hearing loss; NHANES, National Health and Nutrition Examination Survey; NITS, noise-induced threshold shifts.

Su et al, *JAMA-OHNS*, 2011

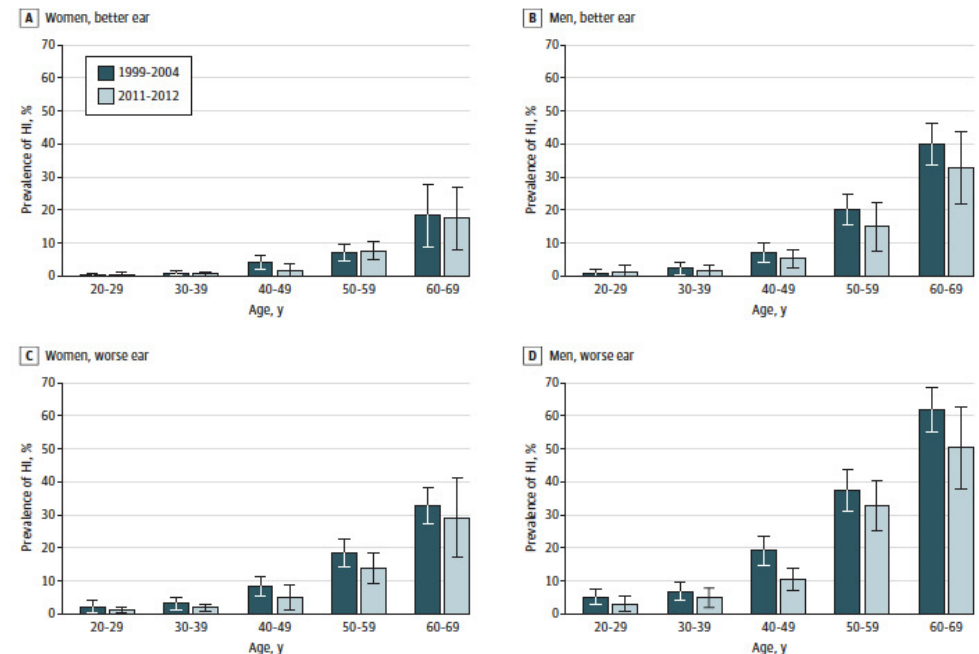
# NIHL in US adults

**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



CDC, *MMWR*, 2017

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



Comparison of the prevalence of speech-frequency HI among adults for the 1999-2004 vs 2011-2012 cycles of the National Health and Nutrition

Examination Survey (NHANES) by age. A, Women, better ear. B, Men, better ear. C, Women, worse ear. D, Men, worse ear. Vertical lines indicate 95% CIs.

Hoffman et al, *JAMA-OHNS*, 2016



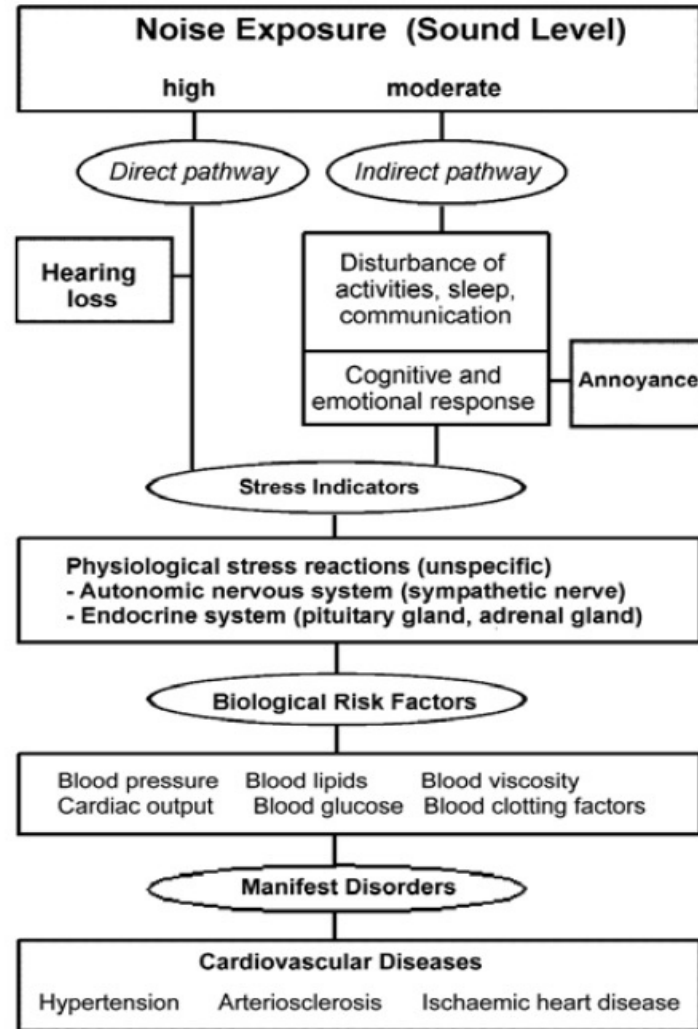
# Economic impacts of NIHL

- 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



© Can Stock Photo

# 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

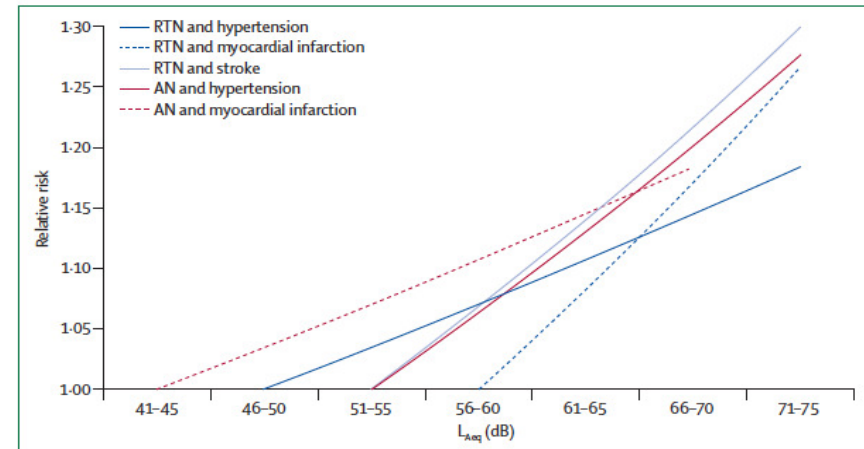


Figure 3: Exposure-response curves of road and aircraft noise and cardiovascular endpoints  
RTN and hypertension (24 studies, noise indicator  $L_{Aeq(16h)}$ ); RTN and myocardial infarction (five studies, noise indicator  $L_{Aeq(16h)}$ ); RTN and stroke (one study, noise indicator  $L_{DN}$ ); AN 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.

- Strong evidence from Europe

# CVD from noise impacts in US

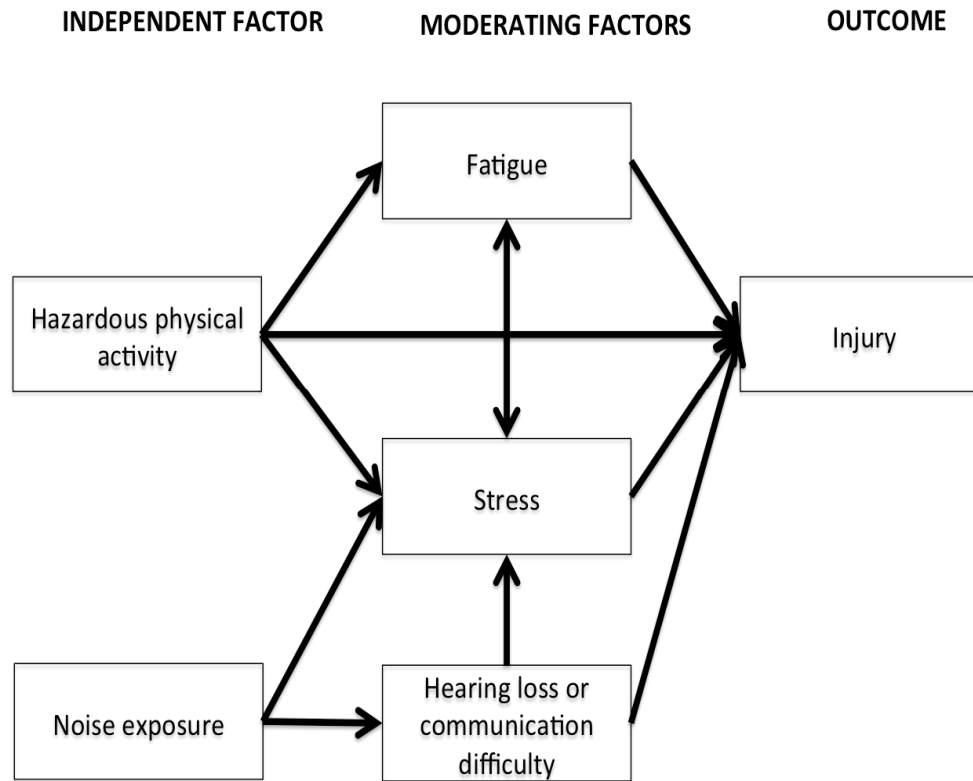
- Estimated CVD savings from 5 dB reduction in US population noise in 2014: \$3.9 billion

Table 3. Model Results

Model	Current situation	5-dB reduction scenario estimate	Difference (current - reduction scenario)
Model 1: coronary heart disease			
Number of people exposed $\geq 55$ 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 $\geq 55$ 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

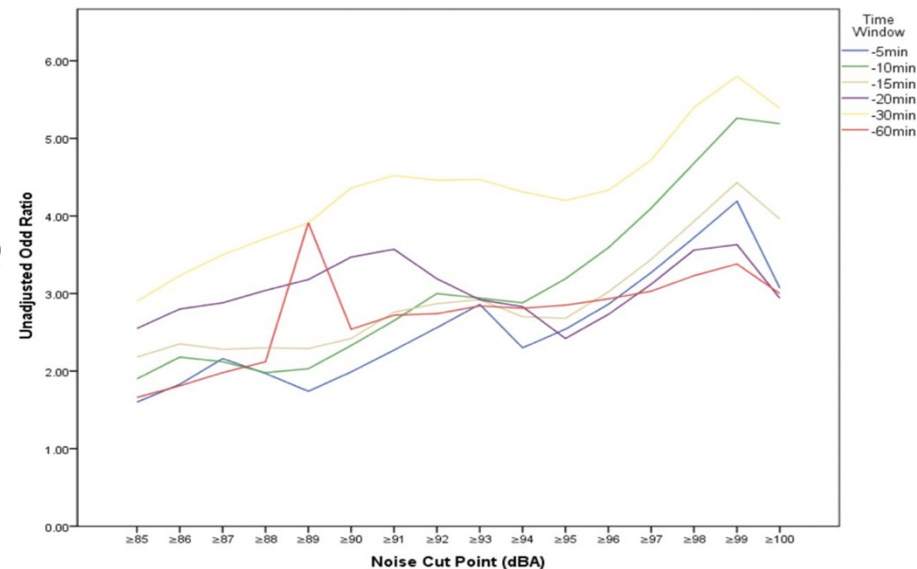
# Noise and injuries



Neitzel, manuscript in preparation

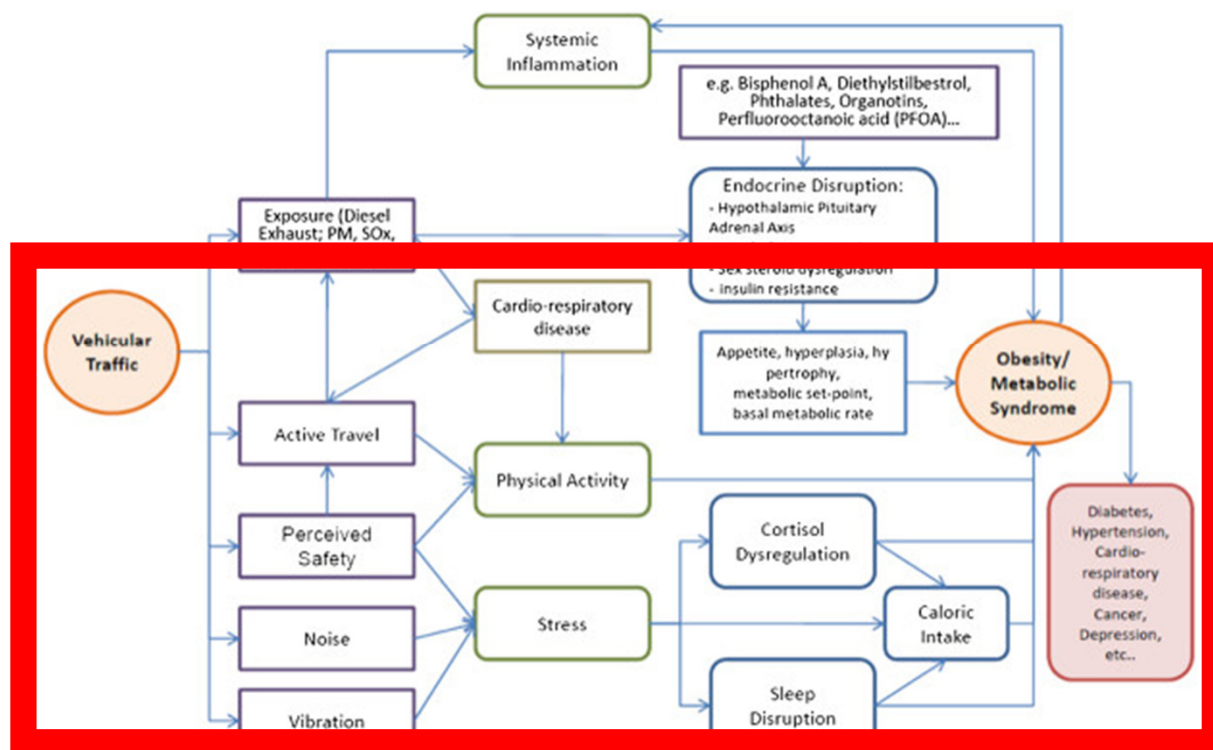
# Evidence for noise → injuries

- 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



# Noise and diabetes

## The Vehicular Traffic and Obesity/Metabolic Syndrome Pathway

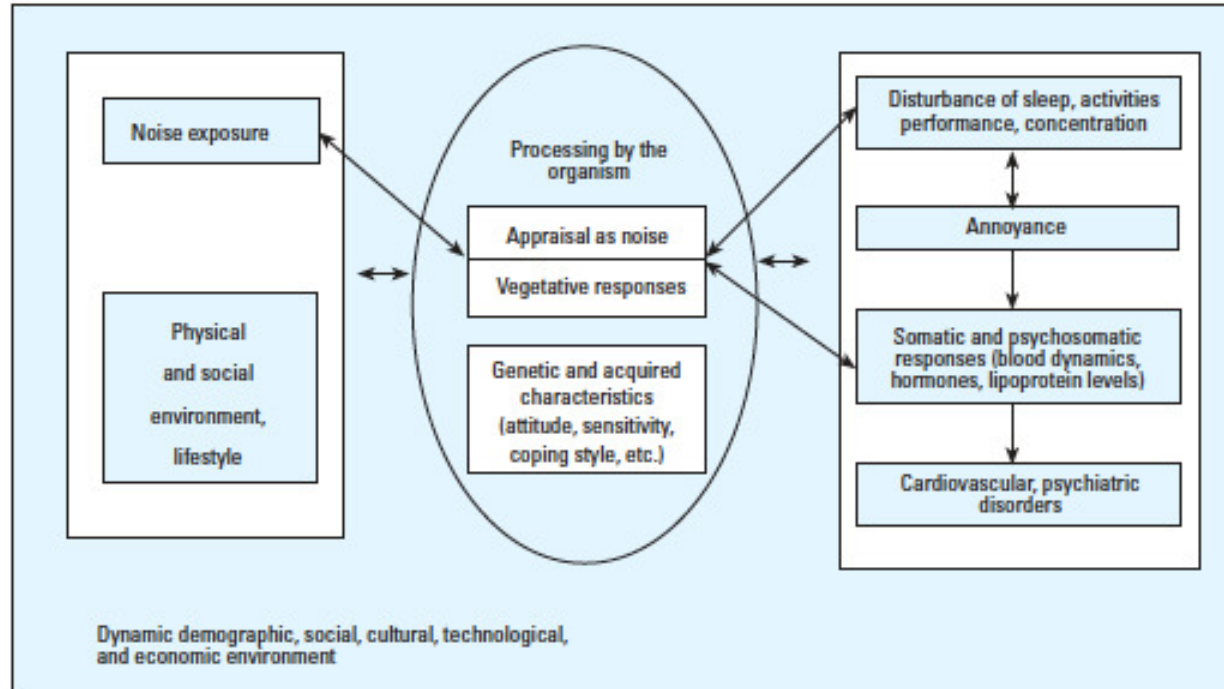


Jerrett et al, *Environ Health*, 2014

# 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

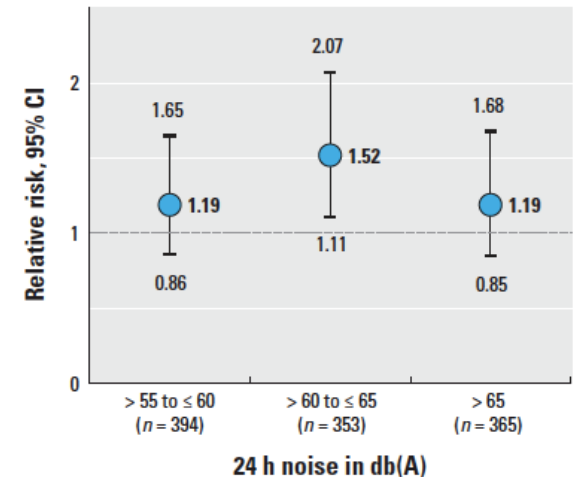


**Figure 1.** Conceptual model of the interaction of noise with humans and the occurrence of effects on health and quality of life (2).

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

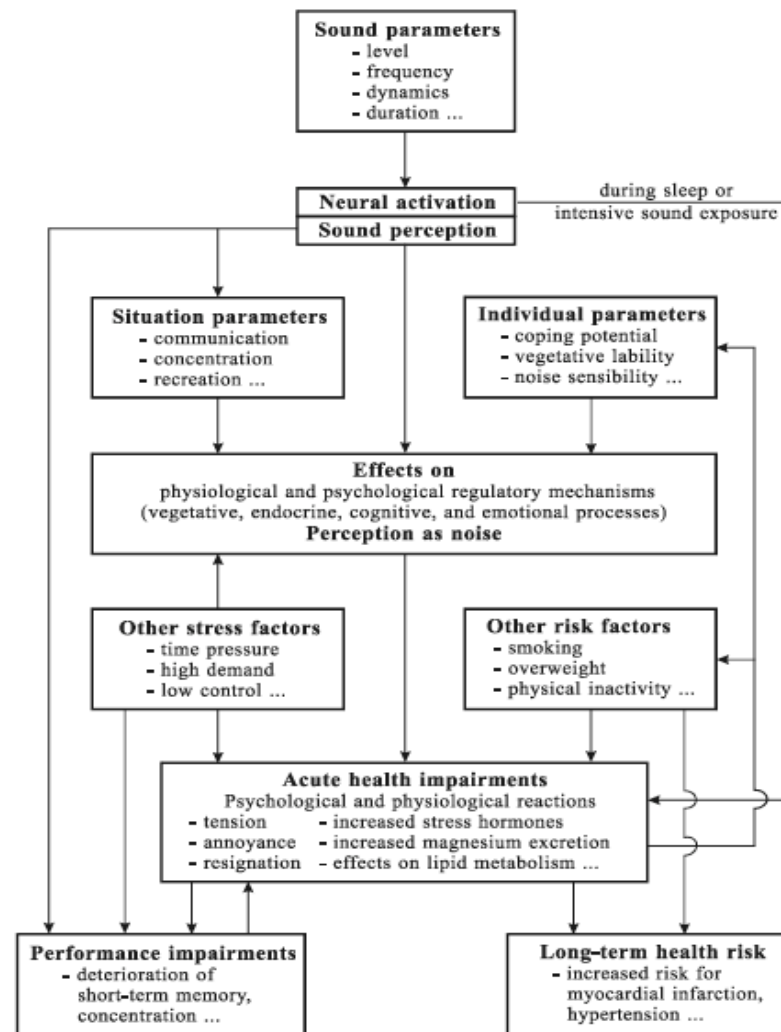


**Figure 2.** Relative risks and 95% confidence intervals of high depressive symptoms at follow-up in association with exposure to different categories of 24-hr noise compared with the lowest noise category [ $\leq 55$  dB(A);  $n = 1,986$ ], adjusted for baseline age, sex, education, income, economic 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

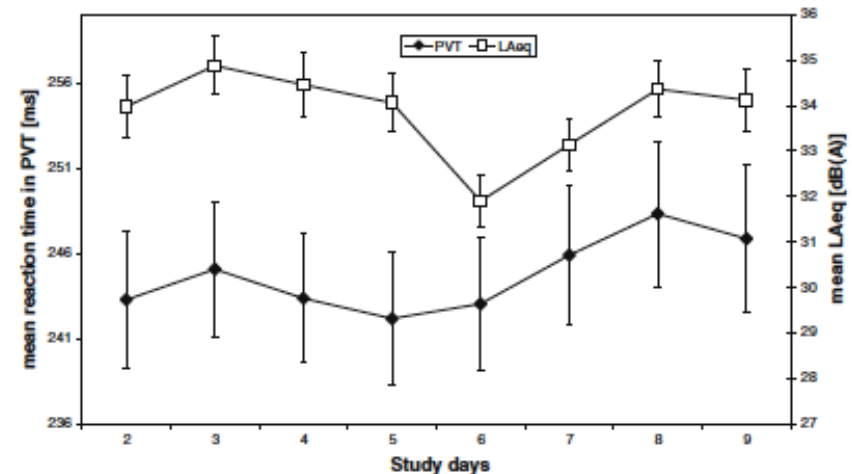


Ising et al, *Noise Health*, 2004

# 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

Fig. 3 Mean reaction time ( $\pm$ SE) in psychomotor vigilance task (PVT) in the course of the study and respective mean energy equivalent noise level (LAeq) ( $\pm$ SE) values during the previous nights of the field study. Day 2 is Wednesday morning and so on



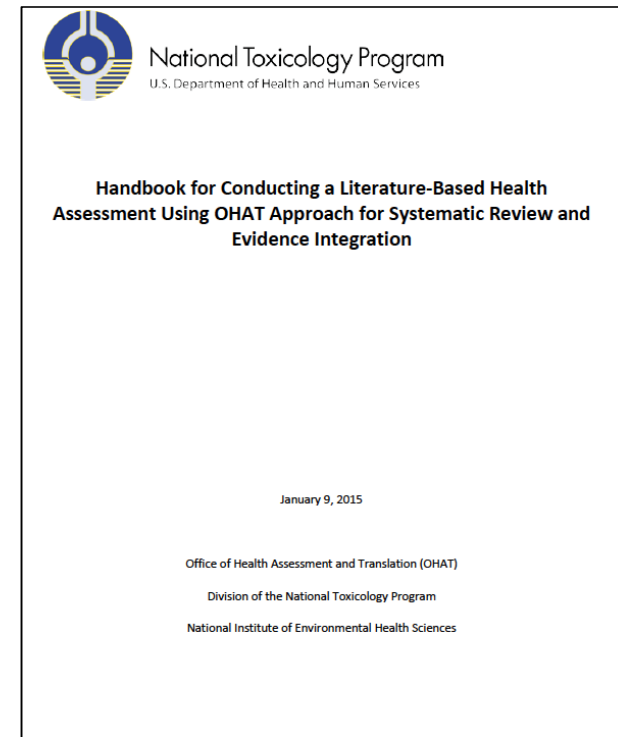
Elmenhorst et al, *Int Arch Occup Environ Health*, 2010

# 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



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

# 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

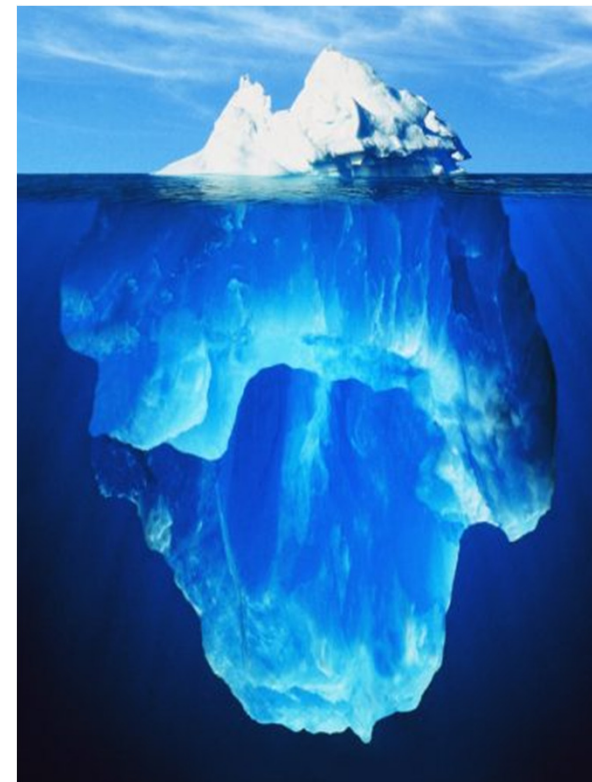
Table 4.1: Guideline values for community noise in specific environments.

Specific environment	Critical health effect(s)	LAeq [dB]	Time base [hours]	LAmx, fast [dB]
Outdoor living area	Serious annoyance, daytime and evening Moderate annoyance, daytime and evening	55 50	16 16	-
Dwelling, indoors	Speech intelligibility and moderate annoyance, daytime and evening	35	16	-
Inside bedrooms	Sleep disturbance, night-time	30	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)	-	-	140 #2
	Hearing impairment (children)	-	-	120 #2
Outdoors in parkland and conservation areas	Disruption of tranquillity	#3		

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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