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Applying a novel environmental health framework theory (I-ACT) to noise pollution policies in the United States, United Kingdom, and the Netherlands

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A comparison of environmental noise pollution policies in the United States, United Kingdom, and the Netherlands using a comprehensive environmental health framework

ABSTRACT

I-ACT is a theoretical framework designed to guide environmental health improvement efforts. “I-ACT” identifies four interacting drivers of change that influence an environmental health aim: (1) Information systems; (2) public Awareness; (3) leadership and Coordination; and, (4) Tools. Actors can use I-ACT to clarify roles and identify strategies to impact their aim.

Here we apply the I-ACT framework to a ubiquitous environmental hazard, noise pollution, comparing three Western countries: the United States, the Netherlands, and the United Kingdom. Our approach statutorily defines each country’s designated aims, qualitatively evaluates its information systems, awareness, coordination, and tools, and assesses the role of these drivers in achieving the aims.

While the Netherlands and the United Kingdom demonstrated robust activity in some drivers, the United States showed limited activity and achievement. There appeared to be an association between achievement of aims and demonstrated elements of each driver, providing support for the utility of I-ACT.

KEY WORDS

noise; environment; policy; public health; framework;

INTRODUCTION

Environmental health arises out of a dynamic, complex ecology, where numerous factors influence public health outcomes. (Nisbet & Gick 2008) To eliminate or reduce harm from an environmental health hazard, social economic models confirm that typical market-based solutions are often insufficient because the creators of a specific hazard rarely bear the full costs associated with the hazard (Sandmo 2015). Instead,

lasting environmental health improvement comes from a multi-prong, multi-method effort involving coordinated leadership and support from a variety of actors (Ostrom 1990).

To help guide efforts to create lasting improvement in the midst of such dynamic complex systems, we have developed a framework, which we call “I-ACT,” that acknowledges that the path to improvement is not linear across time and place. Our objective was to develop a holistic, policy-oriented framework that will allow environmental health researchers, educators, and administrators to identify gaps and essential work that can be accomplished with their unique roles and skillsets. I-ACT can be used by any stakeholder at any level – individual to national health ministry – to offer specific direction based on the analyst’s role and capacity.

I-ACT identifies four key drivers that influence how an environmental health aim will be achieved: (1) “I”: robust Information systems, (2) “A”: level of Awareness; (3) “C”: Coordination and leadership; and (4) “T”: application of evidence-based Tools. (Figure 1) I-ACT is based on principles of law, public health, economics, adaptive management, and improvement theory. As a result, these drivers are far-reaching, qualitatively observable, and can be addressed in multiple ways. I-ACT can be applied prospectively or retrospectively to a variety of chemical, physical, and psychosocial environmental hazards (Figure 1).

The focus on working towards an environmental aim is what differentiates I-ACT from several alternative frameworks that have been proposed primarily in order to identify and quantify environmental public health hazards and assess agency capacity. The Pressure-State-Response (PSR) framework, along with numerous expansions and variations, support I-ACT’s Information driver by guiding the development of appropriate and useful indicators to track driving forces and impacts over time (Gaglio, Shoup & Glasgow 2013; Glasgow, Vogt & Boles 1999; Integrated Environmental Health 2017; Hambling, Weinstein & Slaney 2011). Additional integrated environmental health impact frameworks developed guidelines for more comprehensive identification of the multi-causal and potentially non-linear relationships between the environment and public health assessment (Integrated Environmental Health 2017). They can be thought of as a critical first step toward achieving aims and also part of the ‘Information’ component of the I-ACT framework (Kjellstrom et al. 1995; Briggs et al. 2008; Hambling et al. 2011). The University of Washington’s Northwest Center for Public Health Practice adapted the 10 Essential Services specifically for use by environmental health agencies (Lynn, Fulop, & Wickham 2007). This adaptation is useful in assessing organizational and/or institutional capacity and programmatic gaps but unlike I-ACT, is not intended to plan and measure improvements toward a specific, measurable environmental aim. Other differences between 10 Essential Services and I-ACT are that 10 Essential Services is intended for use by

agencies and not relevant to other actors such as lay persons, advocacy groups, politicians, and industry groups who seek to design or strategically guide initiatives.

I-ACT Drivers

Information is the first driver influencing an environmental health aim, and critically important in part because increased knowledge has the potential to correct some market imperfections. Relevant information includes identification of the sources, types, and severity of pollution, estimation of individual and population exposure, analyses of temporal and geographic patterns, identification of at-risk and vulnerable groups, measuring the severity and extent of exposure-related morbidities, and identification of threshold standards for safety. Information significantly impacts the other three drivers of change by building awareness and promoting coordination and leadership. Without baseline information, there is little motivation to achieve the aim.

The second I-ACT driver influencing environmental health aims is Awareness. Support for an aim requires a certain level of public awareness to support (a) a sense of urgency, (b) a belief that the problem can be solved, and (c) a belief that there is a trustworthy system in place to ensure accountability. Awareness of available information along with accountable leadership ready and willing to use evidence-based tools can result in a motivated, organized society prepared for change (Glasgow, Vogt, & Boles 1999). Analyses of media and educational campaigns are simple ways to measure public awareness, preferences, and beliefs, whereas documenting governmental awareness is less straightforward but vital both at the administrative and political level.

Good Coordination and leadership, the third I-ACT driver, yields a guiding coalition that leverages talent and resources, serves as a communication hub, identifies strategies for action, and builds consensus across citizen, business, and academic sectors. Strategically and systemically creating real improvement in a complex system depends on agents across the policy spectrum learning how to work together to achieve a shared aim (Susskind & Schulman 2012). Measuring the level of coordination takes into account (a) the allocated budget (b) method of financing to assess whether the funding stream is short term or reliable for long term planning purposes, and (c) legal analysis of distribution of authority among levels of government and between government and market.

Environmental policy Tools are techniques with which government wields power to improve or prevent deterioration of the natural environment in accordance with society's values. When people believe that tools are available to achieve the aim, coordination and leadership emerge and resulting information

sharing leads to even greater awareness. Legal tools include policy instruments such as taxes and other economic (dis)incentives, source control through emission limits, spending on infrastructure, altering the informational environment through communicative instruments, altering the built environment, and enforcement action (Gostin 2008; Mickwitz 2003; Vedung 1998). Evidence suggests that some of the most trusted tools include legal regulation of source, market based instruments, and disclosure strategies (Benneworth & Coglianesse 2005).

Noise pollution and public health

Environmental noise is a ubiquitous pollutant that produces acute and chronic stress on exposed individuals and is associated with significant health impacts. Although the lay public may contend that noise pollution's effects are limited to noise-induced hearing loss and annoyance, the overwhelming scientific consensus points to noise pollution as having far more pervasive effects through the "stress process model" of environmental health. Noise pollution taxes and in some cases exceeds the adaptive capacity of an organism, resulting in psychological and biological changes that place individuals at risk of disease (Munzel et al. 2014). Consequences of exposure include sleep disruption and reduced sleep quality, increased risk of cardiovascular disease (including hypertension and myocardial infarction), performance degradation, stress and mental health conditions, and adverse reproductive outcomes (Hammer, Neitzel & Swinburn 2013; Munzel et al. 2014; Munzel et al. 2016). These health effects can occur through direct physical damage or chronic metabolic stress in the hearing mechanism, as well as through hormonal pathways (Parker et al. 2004; Hammer, Neitzel, & Swinburn 2013). The World Health Organization (WHO) estimates that at least one million healthy life years are lost annually due to traffic noise alone (Burden of Disease 2011). This estimate would likely be much higher if additional common sources of environmental noise, including aircraft, rail, and construction noise, were considered.

We applied our I-ACT framework of change to the problem of noise pollution because it is a pervasive element in the natural and built environment and has broad and substantial impacts on environmental health. From an economic standpoint, noise can be considered a classic "negative externality," such as water and air pollution, where the producer of noise does not bear the full cost of its impact (Mishan 1993). Although air and water are widely recognized as resources harvested in an open access situation, creating what economists define as a "tragedy of the commons" situation, quiet environments are rarely treated as a public resource (Management Policies 2006). Due in part to the

insidious effect of an overly simplistic public perception of noise's effects on health, noise pollution is often viewed as an unavoidable by-product of desirable technologies, transportation, and recreational activities.

Despite these unique challenges, control of noise pollution is relatively straightforward compared to other pollutants. While source control is the most cost-effective regulation, accomplishing measurable change to the ecological framework for noise depends upon multiple interventions to address interrelated risk and identify multiple drivers of change (Parker et al. 2004). Applying the I-ACT method to environmental noise will serve to demonstrate how I-ACT can be used as a planning and evaluation framework to improve environmental health. (Figure 1)

In our analysis below, we discuss the I-ACT framework as applied to environmental noise pollution (i.e. unwanted sound in the environment) in the United States (US), the Netherlands, and the United Kingdom (UK). We selected these western countries due to their relative similarities in law, government infrastructure, and economy. For example, each country has a judicial branch, an executive head, and two bodies of elected representatives. All three democracies share a stable and mature government infrastructure designed to protect the health and safety of its populace. However, the US is not in the European Union (EU) and receives neither directives nor guidance from EU Noise Policy. Unlike the US, both the Netherlands and the UK have been members of the EU for some time, and the UK will remain so through at least 2019. The UK and US are larger in both size and population than Netherlands; their cities of over 8 million people likely have greater density of urban noise than smaller Dutch cities (UN 2015). And finally, environmental noise that has been measured in each country suggests that environmental noise in the Netherlands and UK has remained relatively stable over time, while noise in the US has grown. (Fecht et al. 2016; Weber 2013; Hammer, Neitzel & Swinburn 2013)

Our analysis had two goals. The first was to illustrate applications of the dimensions of I-ACT, providing a better understanding of its potential uses in analyzing and planning improvements in environmental health. The second was to offer recommendations for ways in which the framework can be used to plan and implement strategies for change that optimize environmental interventions for noise pollution in particular.

METHODS

Case studies

In the following application of I-ACT, we present brief case studies of noise policy in the US, Netherlands, and UK. In all three countries, the 1970s saw a rise in environmental health regulations related

to noise along with heightened attention towards air and water pollution. All three countries have legislated noise policy goals and granted a leadership role to a specific entity.

The cornerstone of the I-ACT framework is a carefully identified and measurable aim, which entails articulating the specific improvement being sought. We begin our review of each country with a brief discussion of the context and aim of noise pollution regulation. We then apply each of the components of I-ACT. Specifically, we describe each country's information systems, awareness and beliefs, coordination and leadership, and tools and interventions. We then summarize differences and similarities, before exploring how I-ACT may help identify ways to maximize environmental interventions that protect health.

RESULTS

A. Case Study: United States (US)

A1. The aim of US noise control policy

In the US, federal interest in environmental noise pollution peaked in the 1970s, when Congress passed the Noise Control Act in 1972 and gave the US Environmental Protection Agency (EPA) authority to regulate noise emitted from construction equipment, transportation equipment, motors and engines, and electrical and electronic equipment. The aim was “to promote an environment for all Americans free from noise that jeopardizes their health or welfare” (Noise Control Act 1972). In 1978, the EPA's authority was expanded with the Quiet Communities Act. Although the responsible EPA office was dissolved and funding was withdrawn in 1981, over twenty attempts have been made to reinstate the Quiet Communities Act (Congress.gov 2015).

Although the US currently lacks a clear national organizational structure, the aim of “promoting an environment free from noise that jeopardizes health or welfare,” as articulated in the Noise Control Act, has not been repealed and is still in effect. Hence, for the purpose of this paper, we define the US public health aim as eliminating harmful noise exposures for all Americans. Meanwhile, a number of federal agencies have other authority related to noise and health. Workplace noise, for example, is regulated by agencies under the Department of Labor (Occupational Safety and Health Standards 2008). The Department of Housing and Urban Development, and the Department of the Interior, the Federal Aviation Administration, and the Department of Transportation also have authority to set noise limits in some circumstances (Noise Abatement and Control 1996; Procedures for Abatement 2010).

A2. I-ACT framework

a. Information

The key informational element necessary to reach the aim articulated in the Noise Control Act (“promoting an environment for all Americans free from noise that jeopardizes their health and welfare”) is an outcome measure that shows how the number of Americans exposed to harmful noise is changing over time. This is perhaps the largest data gap in the US: there is currently no information system that would specifically measure progress towards the articulated aim. The EPA began to gather baseline information on millions of Americans exposed to unsafe noise levels in the 1970s and 1980s and recommended exposure limits to prevent various health outcomes; these data are now obsolete (“Information on Levels” 1974). The latest estimate suggests that 104 million Americans are exposed to noise that jeopardizes their health, putting them at risk for cardiovascular disease, noise-induced hearing loss, and other health effects (Hammer, Neitzel, & Swinburn, 2013). The lack of US-specific data on these issues impedes movement in the other three I-ACT drivers of change. Awareness, development of tools, and coordination and leadership all depend on specific, accurate, and timely information.

Although current, accurate data with which to measure progress on the aim is limited, other indirectly related information can provide supporting evidence. Two recent national pollution maps of land, by the National Park Service, and water, by the National Oceanic and Atmospheric Administration, highlight the dearth of quiet spaces in the American landscape (Mapping Sound 2014; Airport Noise 2012). Creation of strategic noise maps of road traffic for some cities, counties, and major highways following guidance from the US Federal Highway Administration, can also support efforts to impact noise pollution by capturing one important source of noise (Procedures for Abatement 2010). In addition, air traffic noise complaints are tracked and occasionally compared with noise measurements and air traffic patterns (Noise Oversight Committee 2015). Existing research also provides context on the health cost savings that come from reducing noise levels (Hammer, Neitzel, & Swinburn 2013; Swinburn, Hammer & Neitzel, 2015). However, as a whole, the US appears to have a weak information system with regard to noise pollution.

b. Awareness

Media analysis is one way to understand citizen awareness, preferences, and beliefs. No macro-analysis of noise in the US media has been done, but informal assessment of media coverage suggests that although there is regular local reporting on noise, the media and public do not have a high level of awareness of its health effects (Hammer & Betzler 2013). It is rare that the media educates the public about the health impacts of noise beyond annoyance because noise is rarely framed as a health issue (Fleur 2015).

Media reports also reveal a low level of confidence in noise reduction efforts due to a poor system of accountability (Kelly 2015; Lacy 2015). Even in situations when a single regulatory body or industry is addressed, the media does not suggest that the noise issue can be resolved (Chicagoist 2015). There may be a correlation between lack of health knowledge and low confidence in mitigation options and accountability.

US education efforts in the area of noise pollution appear to address noise-induced hearing loss that individuals can control, but not other environmental noise sources or the other harmful effects of noise. For example, the American Speech-Language-Hearing Association (ASHA) produced a public service announcement addressing hearing loss among older adults ("Speak Up About Hearing Loss" 2016). A university-developed education curriculum for children called Dangerous Decibels is funded by several governmental and nongovernmental organizations (Dangerous Decibels 2015). And, since 2008, the government's National Institutes of Health has been educating parents of 8-12 year olds about noise-induced hearing loss with a project called It's a Noisy Planet ("It's a Noisy Planet" 2015).

Finally, some cities have the potential to use local noise complaint data to create noise control strategies and educate the public. However, dissemination of this information to increase awareness remains rare (New York City 2015).

c. Coordination

Coordination in the US is relatively weak because the federal agency with authority to lead has been effectively restricted from activity for decades. Congress eliminated funding for the Noise Control Act in 1981, but did not repeal the Act (Shapiro 1991). The aim remained and the EPA maintains authority to lead. But without funding, it lacks the resources to lead in practice or coordinate efforts. There is no leader to do the costly work of collecting, analysing, and disseminating data and best practices regarding noise. After the Act's defunding, federal support to states and guidance to local authorities quickly waned (Shapiro 1991). Federal activity in environmental noise control remains divided among numerous agencies, including the Departments of Transportation, Housing and Urban Development, and Interior and the Environmental Protection Agency. Although some local and federal entities track noise complaints, such as the New York City Department of Environmental Protection and the U.S. Federal Aviation Administration, these agencies have distinct missions that do not always emphasize public health or define health protection in the same way (Shapiro 1991). For example, the Department of Labor set a workplace action level of 85 dBA to protect against hearing loss but not the other health effects that arise from workplace noise (Occupational Safety and Health Standards 2008). Affordable housing regulations cite the overarching hazards of noise in

general along with marketability factors, naming a 65 dB Day-Night Noise Level (L_{DN}) as an acceptable noise standard (Noise Abatement and Control 1996).

Due to lack of coordination, these federal government agencies conduct work that can affect other federal, state, or local interests. For example, a town in Texas attempted to regulate noise caused by industrial drilling, but state authorities and, possibly, federal activity may pre-empt its actions (TX HB 40 2015). While some government actions require an environmental impact statement and mitigation measures for activities that change noise levels in a way that impacts health, this requirement varies by location and agency (National Environmental Policy Act 1970).

Efforts targeting the specific aim of reducing harmful noise exposure for the general population are limited to a handful of locally focused community groups and even fewer national organizations. The US possesses several non-profit and industry organizations with noise-related missions, including the American Academy of Audiology, the American Speech-Language-Hearing Association (ASHA), the National Hearing Conservation Association (NHCA), SAE International, The Institute of Noise Control Engineering (INCE), The American Society of Safety Engineers (ASSE), The American National Standards Institute (ANSI), Quiet Communities, and the small but active Noise Pollution Clearinghouse. These organizations work collaboratively with each other and with governmental agencies to disseminate their research in journals and at conferences and to develop voluntary standards and recommendations. Several have publicly supported attempts to reinstate the Quiet Communities Act (H.R. 3384 2015). However, like US federal agencies, most of these groups' missions are limited in scope, and very few include far-reaching educational programs or address the non-hearing related effects of noise exposure.

Coordination between agencies and the private sector can lead to improved information gathering and sharing, potentially affecting the overall environmental health aim. There are some examples of effective coordination in the US. The Dangerous Decibels project and the federal government's It's a Noisy Planet program are examples of collaboration between government, industry, and advocacy organizations with a targeted educational objective. Both efforts primarily target children.

d. Tools

Policy, regulation, and education all have the potential to reduce the environmental health impacts of noise. Source control is arguably the most effective tool for reducing overall noise levels (National Academy 2010). In the US, the EPA passed source control on four types of noise-generating equipment beginning in 1977: air compressors, motorcycles, medium and heavy trucks, and truck-mounted waste compactors. But the extent to which these source control measures reduced noise exposure has not been

studied in the field (Transportation Equipment 1977). The FAA also implemented source control as evidence emerged that this tool results in significant reductions in noise (Waitz, Bernhard, & Hanson 2007). Tools with less robust evidence include taxes, spending and government procurement, mutual agreements, and emission trading schemes (Gostin 2008).

Other strategies to reduce noise exposure include altering the built environment through zoning or noise barriers and altering the informational environment through labeling, educational campaigns, and other disclosure methods (Hammer, Neitzel, & Swinburn 2013). These tools do not directly reduce noise emissions, but may limit exposure. Hundreds of municipal noise ordinances regulate time, manner, and place of noise emission, often through zoning. Some states and cities use building standards such as California's insulation guidelines and sound transmission maximums for walls and flooring (California Noise Insulation Standards 1974). Noise barriers are often built as required remedies in environmental impact statements or highway traffic noise abatement procedures (Procedures for Abatement 2010). Sound insulation programs to mitigate noise for communities around airports exposed to 65 dBA L_{DN} or greater in compliance with the Department of Transportation Aviation Noise Abatement Policy are another example of altering the built environment (Airport Noise Compatibility Planning 1984).

The tools being used to protect health are limited by lack of authority and insufficient information for determining appropriate objectives for noise mitigation tools (Dunlap 2006). Even when the objectives are clear, enforcement mechanisms may not exist. For example, the EPA altered the informational environment through labelling by requiring a Noise Reduction Rating on hearing protection (Hearing Protective Devices 1979; "Noise Pollution Clearinghouse" 2016). After more than 30 years, the EPA office that implemented and enforced this tool has been defunded. The hearing protection market is now unnecessarily restricted by the fact that the EPA has no staff to update obsolete labelling rules. The Centers for Disease Control's National Institute for Occupational Safety and Health (NIOSH) and the Department of Labor's Occupational Safety and Health Administration (OSHA) have made recommendations regarding labelling. But the offices lack enforcement authority and their efforts address only occupational exposures. Nongovernmental organizations, such as NHCA, can also provide input regarding labelling. However, ultimately, the US public relies on self-policing by hearing protection manufacturers.

A3. United States Summary

According to the I-ACT framework, the four drivers are strongly interrelated and dependent on a clear aim. Although the US has a concise and measurable aim and shows evidence of coordination, it lacks leadership to provide guidance toward the aim. In addition, with no clear funding source, the ability to collect and

disseminate meaningful information and best practices is limited. Without this Information, the public likely lacks confidence in its ability to use tools to affect change toward the aim.

B. Case Study: the Netherlands

B1. The Aim of Dutch Noise Control Policy

The Netherlands benefits from a number of measurable aims related to noise exposure. The original aim, as stated in the Dutch Noise Abatement Act of 1976, was to stabilize the percentage of persons annoyed by noise, prevent noise problems, and reduce noise pollution (Noise Abatement Act 1976). These goals have been restated by subsequent National Environmental Policy Plans. One key aim is “to stabilize the percentage of noise-annoyed population at the level of 1985, that is approximately 40%” (National Environmental Policy Plan 1989). Additional sub-policy aims are to cap the number of dwellings with noise exposure levels above 65 or 70 dBA day-evening night equivalent noise level (L_{DEN}) and reduce the noise emissions from vehicles by 2 dB from 1989 levels, with the expectation that vehicles and trains would, in due time, be more quiet due to international regulations (National Environmental Policy Plan 1989).

B2. The I-ACT Framework

a. Information

The Netherlands tracks a number of measures, informing decision-makers and improving the infrastructure of information. Annual field surveys are conducted by the National Bureau of Statistics (CBS). The National Institute of Public Health and the Environment (RIVM) conducts field studies every 4 to 5 years. Additional information is gained from noise maps of exposure levels from road and railway traffic and industrial and aviation activities in conformance with the EU Environmental Noise Directive, also required every 5 years (Council Directive 2011).

Although noise measurement is not required by national regulation, there has been an increase in monitoring activities since 2009 around airports, along highways and railways, and at busy municipal roads in order to compare actual noise levels with those calculated by the mapping systems (Lolkema, Potma, & Jabben 2012). Information on the acoustic situation, trends in emissions, and information on abatement measures is collected. Some monitoring networks and stations present information online. Data are collected in a national database and searchable by zip code (RIVM 2015).

This informational infrastructure allows the Netherlands to assess whether the aims defined in the Noise Abatement Act, the National Environmental Policy Plans, and related regulations have been achieved.

For example, the percentage of people who are highly annoyed by road traffic noise has been constant for over 25 years, at approximately 30% (Franssen et al. 2004; van Kempen & Houthuijs 2009). Around 70% of dwellings are exposed to L_{DEN} noise levels >50 dBA by road, railway or air traffic (Jabben, Verheijen, & Weber 2013). Analysis of noise maps indicated that, in 2011, 2.6 million inhabitants were exposed to noise levels above 55 dBA L_{DEN} due to road traffic within cities (Woudenberg 2013). Some of the most persuasive data reveal that noise contributes approximately 1-4% to the total Disability Adjusted Life Years (DALYs) in the Netherlands (Knoll & Staatsen 2005). Researchers estimate that 36,800 healthy life years are lost due to road and rail noise exposure (Woudenberg et al. 2013). This robust informational environment creates momentum on other fronts.

The Netherlands' information on the burden of disease from noise influences the other drivers by building awareness, mobilizing coordinated leadership, and revealing which tools have been successful. For example, noise monitoring along a high-speed rail line from Amsterdam to Brussels informed citizens and decision-makers regarding the effect of rail noise emissions on dwellings and on the limited impact of existing noise barriers along the tracks. The railway authorities had strong arguments for additional noise abatement measures and are in the process of implementing them on trains, tracks, and rail barriers.

b. Awareness

Awareness, as defined by I-ACT, hinges upon assessing a population's ability to produce a motivated, organized society prepared for change (Hammer et al. 2015). The Dutch Noise Abatement Society (NSG) is an independent non-government organization ("Dutch Noise" 2015). The NSG supports citizens and groups in addressing complaints, financing targeted educational campaigns, and providing information and workshops for the public, noise experts, and other professionals.

The Dutch EPA for the Greater Rotterdam Area has a 24 hour emergency center where citizens can leave noise complaints. Complaints are analysed quarterly and reported to responsible actors, such as industries, airports, municipalities, and road authorities. Notably, the Dutch EPA does not use these complaints for enforcement in most instances; enforcement is conducted by the National Environment and Transport Inspectorate. Rather, this emergency center serves to build awareness through information, showing an example of how I-ACT drivers influence one another.

Campaigns that help individuals act in their own self-interest may not be effective when the producers of the pollutant do not bear all the costs. The PIEK program for quieter trucks delivering at supermarkets addresses truck noise, a negative externality, protecting health and raising awareness. The Dutch Ministry of Environment provided financial support for small innovations that facilitated flexible

deliveries at supermarkets in residential areas. As a result, many companies changed their fleet over to significantly quieter trucks and equipment. Pictures of sleeping children and educational text on the trucks support awareness-raising of the citizens (Noise Abatement Society 2015). This campaign impacted the public's understanding of the effects of noise on health and reduced harmful noise levels.

c. Coordination

The coordination of environmental noise legislation and policy instrumentation is led by the Ministry of Infrastructure and Environment, Directorate of Climate, Air and Noise. National funding of a façade insulation program totals approximately 11 million Euros annually (StatLine 2015). Research funding in environmental health peaked in 1990's, and resulted in a significant increase in information and use of tools. Since then, there has been a drastic reduction in funding of research on noise exposure, health impacts, and scientific support of the implementation of noise policy. Recent funding of research has been approximately 2 million Euros annually. Now, only small-scale studies are funded by the National Institute of Public Health and the Environment, the Netherlands Environmental Assessment Agency, and other research institutes (StatLine 2015).

With leadership from the Ministry of Infrastructure and Environment, the implementation of select noise policies is also a responsibility of national road and railway authorities, provinces, and municipalities, with dedicated budgets partially financed by the national government. The national government provides specific financial support to these local authorities for the insulation of dwellings and the implementation of noise abatement measures in order to achieve the policy goal regarding dwellings with high noise exposure levels. A dedicated bureau of commercial consultants coordinates and monitors this nationwide insulation program.

The Ministry of Infrastructure and Environment also coordinates the implementation of the European Environmental Noise Directive (Environmental Noise Directive 2002) which requires national road and railway authorities, provinces, and larger municipalities in the EU to draft noise maps and action plans every 5 years. The actions and noise abatement measures defined in the Directive's action plans are financed by local municipalities, resulting in a large variation between the cities.

d. Tools

The types of tools being used in the Netherlands to reduce noise are significant and expanding. The primary tools involve source control, government procurement, altering the built environment through building standards and zoning, and altering the informational environment (Weber 2013).

Source control is traditionally considered the most efficient and cost effective way to reduce emissions of a pollutant (Hammer, Neitzel, & Swinburn 2013). In the Netherlands and the rest of the European Union, internationally defined standards have been in place regulating noise emissions from tires and vehicle propulsion of passenger cars, light vans and heavy vehicles, trucks, and machinery (Council Directive 2001/43 Noise Emissions from Tires 2001; Council Directive 2006/EC 1.5.8 on Machinery). Altering the informational environment has less robust evidence of success, but includes the limited use of media campaigns by the Ministry of Infrastructure and Environment, tire labelling, and noise maps in compliance with the European Environmental Noise Directive (On the Implementation... 2011).

Altering the built environment through building standards to reduce noise includes the façade insulation program. This entails insulating dwellings whose 1986 [façade] L_{DEN} noise levels were higher than the regulative emission standard of 60 dBA from road traffic or 65 dBA from railway traffic (Noise Abatement Act 1976). Insulation is financed by the national government and implemented by the national road and railway authorities, provinces, and municipalities.

Preferred noise limits are also in place for new infrastructure as measured at the façades of dwellings (Noise Abatement Act 1976). Limits vary by urban and rural location, as well as by noise source. To achieve these standards, authorities assess, implement, and finance cost-effective measures. When lower limits cannot be met, higher noise exposure levels are allowed in combination with other noise abatement measures to ensure a regulative noise level *within* the dwelling.

Beginning in 2012, noise production ceilings along highways and railways went into effect (Environmental Management Act 2004). To achieve the limits, reduced traffic speeds, low noise road surfaces, and noise barriers were all considered. Domestic focus is now on striving for more stringent limits for propulsion noise and tire noise for vehicles and trains. To reduce air pollution, and simultaneously reduce noise levels, the cities of Utrecht and Rotterdam recently restricted the use of older, diesel vehicles (“Environmental Zones” 2015). From 2018 onward, provinces will employ similar instruments, (noise production ceilings along regional roads), and municipalities will have a simplified system of noise limits for spatial and infrastructure planning (“Environmental Zones” 2015). Restricted zoning will most likely continue to expand in a way that precludes certain types of vehicles from entering the city. Emissions trading and road pricing may also be utilized.

B3. Netherlands Summary

A well-coordinated Dutch administrative body and EU leadership support the Netherlands’ measurable aim of stabilizing the percentage of noise-annoyed population, reducing the number of dwellings with high noise

exposure levels, and reducing road noise by 2 dB from 1989 levels. And although research funds have been cut, Netherlands still boasts a robust information infrastructure. Despite the availability of information, awareness of the health effects of noise is limited and public momentum usually arises only when there are upcoming changes in noise emissions, for example from a new wind turbine or industry ("Windmolens tasten dorpsgezicht niet aan" 2014). New tools are still being tested and implemented to accomplish the aims. (Figure 2)

C. Case Study: United Kingdom

C1. The Aim of the UK noise policy

England was among the first countries to confront the phenomena of large-scale noise and to develop associated case law and legislation (Coase 1960). In 1960, Parliament commissioned an investigation into 'the nature, sources and effects of the problem of noise and to advise what further measures can be taken to mitigate it' (Goldsmith 2012, 205). Civic engagement also began early. The Noise Abatement Society (NAS) was founded in 1959 and successfully lobbied Parliament to pass the Noise Abatement Act of 1960, in which certain forms of street noise were defined as a statutory nuisance (Noise Abatement Society 2015). The historical role of civil society organizations in influencing UK noise policy continues to this day.

The next major pieces of noise legislation after the Noise Abatement Act were the Control of Pollution Act 1974 (CoPA 1974) which provided a variety of powers to local authorities to deal with noise in construction sites (Peters, Smith, & Hollins 2011), and the Health and Safety at Work Act 1974, which was the first attempt to systematically address workplace hazards including noise (Peters et al. 2011). The powers of local authorities to address residential noise issues were dramatically increased by the Environmental Protection Act 1990, with further amendments by the Noise and Statutory Nuisance Act 1993, the Noise Act 1996, the Anti-Social Behavior Act 2003, the Housing Act 2004, the Clean Neighborhoods and Environmental Act 2005, and the Anti-Social Behavior, Crime, and Policing Act 2014. Noise-related workplace safety regulations were also gradually expanded to many industries. Standards were tightened via the Control of Noise at Work Regulations 2005 (S.I. 2005/1643) which implemented EU Directive 2003/10/EC (since amended by Regulations 2009 S.I 2009/693) that impacts all of the EU, including the Netherlands as described above (Peters et al. 2011).

The aim of the UK noise policy is to "promote good health and a good quality of life through the effective management of noise," as stated in the Noise Policy Statement for England 2010 (Environmental

Noise Directive 2014). More specifically, echoing a long-standing principle in English noise legislation, this aim is translated as an attempt to minimize noise “as far as reasonably practical” using the “best practicable means” (BPM). The aim is thus an evolving concept, to be judged against subjective criteria that adapts to changing economic, social, and technical realities. As a result, taking measurements to track progress and assess whether the aim has been achieved is problematic.

C2. I-ACT framework

a. Information

The UK has a history of a robust informational framework to inform spending and decision-making, beginning with the 1963 Wilson Committee Report on “the Problem of Noise”, which deployed modern research methods to study the problem of noise across all dimensions of society, developing the concept of noise contour maps still in use today.

More recent maps estimate the exposure to major sources of noise (road, rail, infrastructure aircraft, machinery) in built-up areas and areas of particular sensitivity (schools, hospitals etc.) (“European Commission” 2015). In the UK, the Department for Environment, Food and Rural Affairs (DEFRA) is charged with the task of creating strategic noise maps to implement the Directive in England, with Wales, Northern Ireland and Scotland taking responsibility for their own localities. The first round of mapping took place in 2007. It provided DEFRA with the necessary information to set up a framework for prioritizing the worst affected areas and to calculate the costs of transport noise. The second round of noise mapping took place in 2012, with the resulting noise maps published online in 2014 (Environmental Noise Directive 2014).

Data generated as a result of noise mapping led DEFRA to estimate the amenity-value and direct health costs of exposure to road traffic noise at between £7-10 billion per annum in England (Environmental Noise Directive 2014). These figures are now being used in cost-benefit analyses of potential abatement actions, such as the use of low-noise road surfaces. In addition, the maps were used to identify the top 1% of the worst noise-affected households, in order to give these areas priority for investigation. In keeping with the national aims, any final policy resolution as a result of these investigations takes into account local priorities and budgetary constraints. So results may vary between local authorities (Environmental Noise Directive 2014).

Three London-area airports – Heathrow, Gatwick and Stansted – are designated under section 79 of the Civil Aviation Act (1982), giving the Secretary of State for Transport the authority to put in place noise mitigation measures. In addition, 17 airports in the UK each generate their own noise maps and create local

action plans specific to their circumstances under the Environmental Noise Directive round one cycle of mapping noise (Environmental Noise Directive 2014). Tools adopted as a result of this exercise include acoustic insulation schemes for affected homes, compensation schemes, noise monitoring, and limits on airplane ground running.

b. Awareness

In addition to the NAS, discussed above, there are a number of civic and non-governmental organizations in the UK that are actively involved in educating the public and lobbying the government on noise control issues. The 15 year old UK Noise Association (UKNA) campaigns and lobbies for changes in Government policy to tackle noise more effectively (Stewart 2015). Together, the NAS and UKNA publicize April 29th as International Noise Awareness Day and both promote a "Noise Manifesto", calling on the Government to pursue six specific measures to improve the noise climate.

Other organizations that engage with noise issues include the National Society for Clean Air and Environmental Protection (NSCA), which produces an annual National Noise Survey of local Environmental Health officers, and the Chartered Institute of Environmental Health (CIEH 2015), which conducts an annual survey of local noise enforcement activity (Hawke et al. 2006). The information gathered from these surveys resulted in public awareness that was used to inform the tools used in DEFRA policy on noise from mobile food vendors, changes to the entertainment licensing regime, as well as research into the effectiveness of noise policy interventions (CIEH 2015).

UK media are highly active in disseminating information about the health effects of noise. Recent examples include stories on higher stroke risk linked with road noise ("Noisy Roads" 2015), rising risk of obesity associated with traffic noise (Khomani 2015), and early deaths linked with high levels of noise pollution ("London Deaths" 2015).

Following the EU directive, DEFRA publicizes their work and maintains a facility for the public to view noise maps and search for information specific to particular postcodes (Environmental Noise Directive 2014). Overall and especially since the Freedom of Information Act was passed in 2000, the UK government has made significant progress in releasing both raw and processed data freely for both public and research use.

c. Coordination

Institutional responsibility for noise control in England is distributed across several governmental entities. In Wales, Northern Ireland and Scotland, control over housing and environment policy is controlled locally. The Health and Safety Executive (HSE) oversees noise in the workplace. The Civil Aviation

Authority (CAA) and Department for Transport deal with noise at airports. And, local authorities are responsible for addressing most of the day-to-day issues of noise regarding construction, neighbour noise, and other statutory nuisance complaints. DEFRA has overall responsibility for managing noise policy in England, fulfilling EU directives, and providing guidance to achieve the national aim.

Local authorities have authority to ensure compliance with building regulations, deal with statutory nuisance noise, and monitor noise at night. Local powers include imposing monetary fines and/or seizing offending equipment. However the authority to monitor night noise is voluntary. Because the costs of these activities must come from local authority general funds (Peters et al. 2011), the quality and quantity of night time noise enforcement vary considerably across localities of differing wealth and priorities. For example, Manchester City Council (Cox 2014) appears not to maintain a night noise service at all; the relatively noisy central London Borough of Camden operates a night-time noise patrol solely on Friday and Saturday nights from 10pm to 4am; and, the wealthier Royal Borough of Kensington and Chelsea maintains their night noise patrol seven days a week between 7am and either 3am (M-W) or 5am (the rest of the week) (“Kensington Night Noise” 2015).

Government funding of DEFRA and block grants to local authorities and Wales, Northern Ireland, and Scotland, has fallen considerably after the financial crisis of 2007, with DEFRA suffering some of the worst budget cuts among all agencies. Spending in the category most relevant to noise control, "help to enhance the environment and biodiversity," has fallen from £465 million in 2010-2011 to £314 million in the 2015-2016 budget (Environmental Noise Directive 2014). Local authority budgets have also faced cuts. However, total local spending on the category of "environmental protection" has been gradually increasing, from £158 million in 2009-2010 to £180 million. Furthermore, for the 2012-2013 fiscal year the category was renamed “Environmental protection; noise and nuisance,” illustrating the growing awareness and importance of noise as a key element of environmental health (Local Authority... 2014).

A main objective of DEFRA remains the provision of guidance on best practice techniques for local authorities, a key indicator that coordination and leadership is present. The implementation of the Environmental Noise Directive also improved coordination because it prompted interagency collaboration. The Department of Health included noise as a determinant of health in their Public Health Outcomes Framework, which helped facilitate interest in including places of tranquility under the National Planning Policy Framework (Environmental Noise Directive 2014).

d. Tools

The UK uses a number of tools in pursuit of their aim to minimize noise “as far as reasonably practical” using the BPM. The EU directive and The Wilson Report recommend that noise policy focus on prevention and reduction of environmental noise to achieve the aim. A wide range of tools, including traffic smoothing measures, quieter road surfaces, better construction standards, and even rubber bin lids, indicate that this principle continues to guide noise policy (Goldsmith 2012).

Environmental noise created by industry is regulated through a system of source control and permits. The Pollution Prevention and Control (England and Wales) Regulations of 2000 introduced an integrated approach to the regulation of certain industrial activities to be enforced by the Environment Agency (Penn 2002). As amended by the Environmental Permitting Regulations 2007 and 2010 (S.I 2010/675), these Regulations include a system of environmental permitting based on the best available technology (Peters et al. 2011). Limits on acceptable exposure levels of workers to noise and vibration are in the Control of Noise at Work Regulations 2005 (S.I. 2005/1643) which implemented EU Directive 2003/10/EC (since amended by Regulations 2009 S.I 2009/693) (Peters et al. 2011). In addition to setting minimum standards for health and safety, the legislation allows compensation to be awarded in some cases (Peters et al. 2011). The Health and Safety Executive (HSE) maintains a list of case studies where workplace noise has been effectively managed through control techniques such as isolation, substitution, and acoustic absorption (Case Studies 2015).

Airport noise is also limited through source control, as noisy aircraft are being gradually phased out via the imposition of increasingly stringent aircraft certification standards. In addition, Act 1982 gives the Civil Aviation Authority (CAA) and the Department of Transport authority to specify minimum noise routes, limit the frequency of takeoffs and landings, and control the proportion of flights of particular types of aircraft (CAP 1165 2014).

Altering built environments is another tool being used to achieve the aim. Grants are available for acoustic insulation of effected homes near airports (Goldsmith 2012). Local authorities may provide guidance on measuring and specifying noise limits and insulation targets for floors and walls for new or newly converted dwellings (Stookes 2005).

When government regulation is insufficient, the Environmental Protection 1990 Act expanded the definition of noise as statutory nuisance (e.g. that can be dealt with in the criminal courts) and specifically allowed for recourse to the civil courts to secure injunctions if necessary. For noise to constitute a statutory nuisance it must either be prejudicial to health or a nuisance, although arguing the former likely requires authoritative scientific evidence (Hawke et al. 2006). Furthermore, businesses have a defense of “best

practicable means” (BPM). When a complaint is filed, the relevant local Environmental Health officer considers the level, type, duration, time of day, and number of people affected when judging whether a noise is a statutory nuisance. They may also weigh the characteristics of the neighborhood and the circumstances (Hawke et al. 2006). If a statutory nuisance is found to exist, to possibly occur, or to possibly recur, the local authority has a duty to implement a relevant remedy, e.g. serving an abatement notice or prohibiting/restricting an occurrence, if required (Peters et al. 2011; Hawke et al. 2006). This process is widely used. For example, in the 2013-2014 CIEH survey of local authority noise enforcement activity, the 150 local authorities who responded (43%) recorded 145,514 noise complaints (representing 5,186 per million population). Of those, 120,950 were “resolved”, and 37,105 were categorized as incidences of “statutory nuisances”, subject to formal enforcement power (CIEH 2015).

C3. United Kingdom Summary

UK’s noise policy does not have a measurable aim and its tools to reduce noise are used moderately. However, accessible information and clear leadership have likely led to robust public awareness. Implementation of the EU directive also has prompted improvements in coordination in line with the UK approach of promoting best practices. (Figure 2)

DISCUSSION

We have illustrated applications of the dimensions of the I-ACT framework through an analysis of environmental noise pollution policy in the US, the Netherlands, and the UK. Our analysis reveals areas of strength and weakness that can be targeted by various actors to improve environmental health. Looking across all three countries, the need for accurate and complete Information on exposure assessments that can be compared over time and across geographic areas is the most pressing need. This type of Information has the potential to serve as the foundation of tracking progress over time. A number of I-ACT drivers are influenced by the EU participation of the Netherlands and the UK; the EU machinery directive increases Awareness through noise labels, and the Environmental Noise Directive strengthens the Information driver by mapping the noise levels of larger municipalities (Council Directive 2002/49/EC; Council Directive 2006/42/EC).

The US aim to eliminate harmful noise exposures among all Americans has not been achieved. In fact, harmful noise exposures appear to have grown from 66 to 104 million Americans (Hammer, Neitzel, & Swinburn 2013). Although there is some coordination across sectors in the US, the US effort lacks strong leadership and significant funding. Revealing limited information, awareness, leadership, and tools, I-ACT

analysis suggests several promising areas for targeted efforts. (Figure 2) Adopting similar strategies that led to the high level of Awareness in the UK could benefit the US, especially given the vital role that interests non-governmental organizations play in both countries. Restoring and adequately funding the Quiet Communities Act, directly targeting the leadership and coordination driver, would likely provide a significant boost to all the other drivers. To accomplish this, researchers could collect and share meaningful information with the public. Community groups could use that information, shifting their focus to direct advocacy. And non-governmental organizations could fund and disseminate relevant research specific to the aim.

The Netherlands' aims are less ambitious, but significant progress has been achieved with a robust information system and recognized leadership and coordination among national and local governments and the private sector. (Figure 2) Regarding the first aim to stabilize the percentage of noise-annoyed population at the 1985 level, field studies suggest that the percentage of annoyed inhabitants has been stable (Weber 2013). The second aim to cap the number of dwellings with noise exposure levels above 65 or 70 dB L_{DEN} at all households is on track, with an insulation program that has been expanded several times. Noise emissions from road traffic have not decreased 2 dB to accomplish the third aim, despite the implementation of more stringent source limits (Weber 2013). Dutch noise policy in conjunction with the implementation of the EU's Environmental Noise Directive has been effective in addressing excessive noise and noise exposure peaks. While the Netherlands' smaller population and government infrastructure may lend itself more readily to a well-integrated noise program, the Dutch example suggests that a strong presence of all I-ACT drivers increases the likelihood of achieving a measurable environmental health aim. And while the Dutch succeed in articulating and achieving their measurable aims to a large extent, their aims may be misdirecting focus away from the larger public health implications of noise in favour of annoyance. The US aim of eliminating, or at least reducing noise harmful to the public health may be worth considering.

Measuring progress on the UK aim to minimize noise as far as reasonably practical using the BPM is difficult given the subjective nature of the aim. However, the UK has a relatively robust information system and a collection of BPM tools. Estimates of aggregate change in noise levels across the UK was not available, but within London, Fecht et al. (2016) find little change in road noise levels between 2003 and 2010. Compared to the US and the Netherlands, the UK also benefits from strong public awareness and more sophisticated non-governmental organizations. DEFRA reports that as of January 2014, 35% of the 1% worst affected households identified in the EU Environmental Noise Directive's Round 1 Noise Action Plans have been investigated and/or resolved (Peters et al. 2011). Unfortunately, local night noise

monitoring remains inconsistent. In general, the government's explicit reliance on cost-benefit analysis for guiding noise policy makes it particularly receptive to evidence-based arguments. Therefore, as scientific evidence on the public health costs of noise increases, the framework is in place for legislation and enforcement to grow. The Netherlands has the potential to serve as a model in Coordination because there is a process to measure and publicize positive progress over time through annual reports to the parliament from an independent research institute. Efforts targeted at clarifying the aim with measurable objectives and consideration of additional tools would likely contribute significantly toward achieving the aim.

Progress in environmental health can seem elusive without a specific aim and a broad roadmap. I-ACT creates the roadmap with roles for researchers, educators, administrators, industry, and citizens. Actors can use this model to help clarify the aim, assess how their work influences the primary drivers of change, and plan strategic efforts to impact their aim.

CONCLUSIONS

Analyses based on I-ACT can facilitate better-informed decision making to plan and implement strategies for optimizing environmental health interventions. Using I-ACT to compare noise pollution policy in the US, the Netherlands, and the UK, we have described each country's efforts to protect health and improve the environment. The four drivers of change we have identified (information, awareness, coordination, and tools) are critical to achieving environmental health aims. While all four drivers are critical components of environmental health improvement, further research is needed to explore which measures within I-ACT are the most appropriate in various cultural, political, and socioeconomic contexts and for different specific environmental health challenges. Further application to other environmental pollutants and to different countries' environmental health initiatives will help improve and refine the I-ACT framework, as well as our understanding of interventions designed to improve environmental health.

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FIGURES

Figure 1 Envisioning Environmental Health Improvement through I-ACT

Figure 2 International Comparison of Environmental Noise Pollution Policy