



A conceptual model of environmental noise interventions and human health effects

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This model builds on a framework borrowed from the air pollution field – from so-called air pollution accountability research - that has been utilized to evaluate whether actions taken to improve air quality have resulted in reduced health effects. The air pollution framework puts most emphasis on ambient concentrations of air pollutants and this has less relevance for environmental noise. Peoples' noise exposure is strongly influenced by the propagation paths from sources to receivers, and hence highly dependent not only on emission levels but on the disposition of receivers relative to sources. Propagation paths need to be included as a component of the system in the causal pathway between environmental noise sources and human health effects. Another difference is that air pollution accountability research has tended to focus on regulatory interventions to reduce emissions, examining whether this intervention consequently reduces ambient concentrations over time. While regulatory intervention is also used in managing environmental noise, for example by control of vehicle source levels, there is a much broader set of interventions that is utilized in environmental noise management - five broad categories of intervention can be identified. The model will provide a framework for organizing, in a search for evidence in the noise literature, a synthesis of the impacts of environmental noise interventions on human health outcomes.

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1 INTRODUCTION

This paper communicates work that is a forerunner to undertaking a systematic literature review of the effects of environmental noise interventions on human health outcomes. It describes the development of a model, or framework, that classifies types of environmental noise interventions that may lead to changes in human health outcomes. The literature review to follow will address the question of the nature and quality of the evidence on the impacts of *environmental noise interventions* (or *noise management actions*, or *noise control activities*) on the general population or on specific subpopulations. Given the absence of an existing model for consideration of the interventions-outcomes relationship for environmental noise sources, this paper provides the rationale and the description of such a model.

The sources of noise considered here as environmental noise include roadways, railways, air traffic and wind turbines etc. For these sources, the relevant exposures of the general population are the levels of these noises at the external façades of their dwellings. This will be what most of the literature on effects of these sources in residential settings will report. For more specific settings: such as patients in hospitals, environmental noise sources may be considered as all sounds heard in a hospital ward, and their exposures the levels experienced at their patients' bed positions. For other settings and subpopulations (say young people who use personal listening devices and/or attend music events) the environmental noise exposure may be the sound delivered to the users' ears through the headphones of personal listening devices, or the exposure experienced when attending music events or similar. A model for consideration of the interventions-outcomes relationship for environmental noise will be most useful if its framework can be generically applicable across most environmental noise sources (adopting a broad definition of what noises may be considered to be environmental), and across most settings in which health effects of noise may be of interest.

The adverse health outcomes of environmental noise exposure considered include sleep disturbance, annoyance, cognitive impairment (of children), mental health and wellbeing, cardiovascular diseases, and hearing impairment and tinnitus - but again the generic nature of the framework could equally encompass any other effect or outcome of interest.

The possible noise interventions are also broad. The intent is that the framework should comprehensively incorporate all noise management or noise control strategies that are, or could be, practiced for all sources of environmental noise. Interventions will include, for example, exposure-related actions that aim to change the level of noise exposure of people, as well as actions that are non-exposure-related. The direct, or indirect, intent of both the exposure-related interventions and the non-exposure-related interventions will be to change (generally reduce) the magnitude of adverse health outcomes.

2 A FRAMEWORK FOR ENVIRONMENTAL NOISE INTERVENTIONS

The different environmental noise sources under consideration, and the different types of interventions possible for each source, introduce considerable complexity to a review of health effects of interventions. To provide structure for such a review we have developed a framework, or conceptual model, for environmental noise interventions leading to changes in health outcomes. This model builds on frameworks previously adopted in the air pollution field utilized to evaluate whether actions taken to improve air quality have resulted in reduced health effects – so-called *air pollution accountability research* (NRC, 2002; HEI, 2003; van Erp et al., 2012;

Burns et al., 2014). Fig. 1 is an example of a common air pollution accountability research framework.

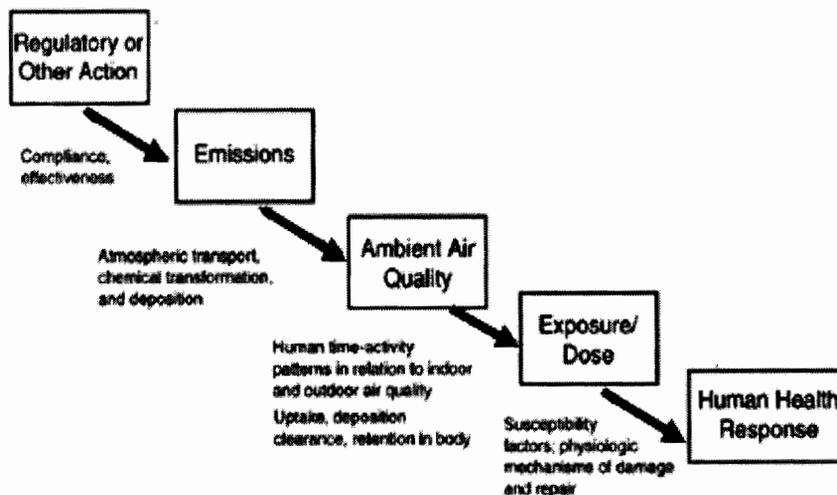


Fig. 1 – Framework chain of accountability used in the air pollution field, Each box is a component in the link between regulatory action and health responses to air pollution. Modified from HEI (2003).

A characteristic of frameworks used for air pollution is the emphasis put on *ambient air quality*, specified as the concentrations of air pollutants in the atmosphere, as a key component in the chain of accountability. This notion of ambient quality has less relevance in the environmental noise field. Noise exposure of people is strongly influenced by the length and nature of the propagation paths from sources to receivers, and hence highly dependent not only on emission levels but on the disposition of receivers relative to sources. Propagation paths thus need to be included as a system component in the causal pathway between environmental noise and human health effects. Fig. 2 depicts the basic system components of a causal pathway between noise sources and human health effects that incorporates the propagation path. It is the base model appropriate for consideration of environmental noise interventions. Note that in this form it can be considered as a generic framework suitable for all environmental noise sources and interventions.

Another difference is that air pollution accountability research has tended to focus on regulatory interventions directed at reducing emissions, examining whether this intervention consequently reduces ambient concentrations over time. While regulatory intervention is also used in managing environmental noise, for example by control of aircraft or road vehicle source levels, there is a much broader set of interventions that is utilized in environmental noise management (e.g. WHO, 1999; Chapter 5). *Environmental noise management*, or *environmental noise control*, includes technical interventions that embrace, for example, reduction of levels at the source, positioning of outdoor barriers between source and receivers, and changes in the acoustic properties of building envelopes to reduce levels at receivers. Levels at the receiver may also be reduced by hearing protection. Potential interventions also includes other source-related changes such as time restrictions on operations, as well as major source changes that are likely to result from changes in the infrastructure provided. Examples of the latter type of interventions may include the opening or closure of new roadways and railway lines, bypass roadways, or

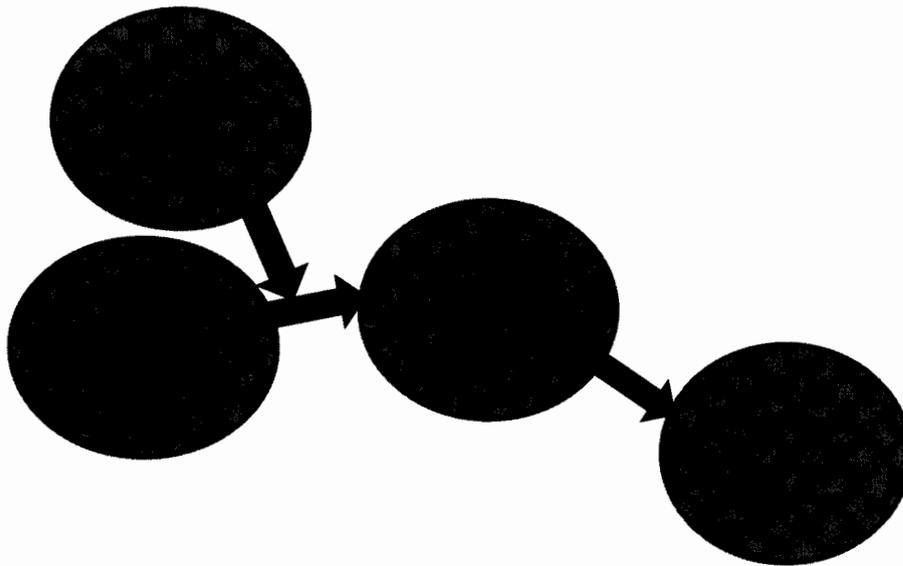


Fig. 2 – Basic system components of the causal pathway between environmental noise and human health effects for the consideration of potential interventions and subsequent changes in human health outcomes.

major changes in traffic load on transport routes, or the opening of new airports/runways and consequent rearrangement of air traffic load on different flight paths. Environmental noise management has also utilised interventions that can be considered behavioural. For example, educational campaigns may promote behaviours that reduce peoples' exposures, as in campaigns directed at young people regarding the levels at which they listen to live or recorded music. Or a campaign may be directed at mitigating adverse community reaction by attempting to build trust between a noise maker, say an airport operator, and the surrounding community, regarding forthcoming changes in flight operations.

Based partly on intervention literature, but also on the authors' familiarity with several decades of environmental noise management, we have categorised environmental noise interventions. Such categorisation is necessary as later synthesis of evidence regarding outcomes from interventions may only be appropriate when conducted across studies that belong to the same intervention category. We have identified five broad categories of intervention – as listed in Table 1, and these apply at various points along the system pathway between sources and health outcomes. The list of intervention categories is intended to provide a systematic and comprehensive basis for any future work with respect to environmental noise interventions and health effects.

Terminologies for two of the technical interventions included in Table 1 have been borrowed from the environmental noise control field (*source interventions* and *path interventions*). A third category of intervention is termed *infrastructure change intervention*, and others are termed *indirect interventions*, and *change in behavior interventions*. The categories and sub-categories of these intervention types are largely self-explanatory, but also illustrated by the examples included in TABLE 1.

Table 1 – Categorization of Environmental Noise Interventions

Type	Intervention Category	Intervention Sub-category	Examples
A	Source interventions	Change in emission levels of sources	motor vehicle emission regulation; playback levels personal listening devices; rail grinding; road surface
		Time restrictions on source operations	airport curfew, heavy vehicle curfew
B	Path interventions	Change in the path between source and receiver	noise barrier; creation of dwelling quiet side
		Path control through insulation of receiver/receiver's dwelling	insulation of building envelope
C	Infrastructure change interventions	New or removed infrastructure, or change in traffic load on existing infrastructure	new flight path; construction of town bypass; new wind farm; major changes in rail freight load, or road traffic load
		Distance controls between (new) receivers and sources	urban planning control; 'buffer' requirements
D	Indirect Intervention	Change in other dimensions of dwelling/neighborhood	green space provision in neighborhood; quiet side
E	Change in behavior interventions	Change in individual behavior to reduce exposures; avoidance or duration of exposure	education regarding playback levels on personal listening devices, or potential hearing damage through loud music
		Community education, communication	changing opinions regarding sources, or explaining reason for noise changes

3 OUTCOME MEASUREMENTS FOR EXAMINATION OF CHANGES IN HEALTH OUTCOMES ARISING FROM INTERVENTIONS

The environmental noise interventions described above will result in changes in various outcomes along the system pathway between noise sources and human health responses.

Evidence of the effect of an environmental noise intervention on human health will be based primarily on synthesis of studies in which the effect of the intervention has been related directly to a change in health outcome. The availability of a measured change in health outcomes in an intervention study will ensure it is included in further synthesis of intervention-outcome relationships.

However, on the assumption that there is a well-established link between exposure and a particular health outcome, it is not necessary to evaluate interventions only by means of change in measured health outcome; evaluation by the *intermediate outcome* of change in exposure of a population of interest is also appropriate. Change in exposure can be presumed to result in change in health outcome. Thus studies located in the literature that report a change in the exposures of the population of interest will also be selected for further synthesis of the effects of environmental noise interventions on health outcomes.

In addition, certain behavioral environmental noise interventions directed at changing knowledge or attitude may result in change in exposure of a group (for example, an intervention directed at the education of users regarding the potential damage from high playback levels of personal hearing devices may result in lower playback levels). They also may result directly in changes in health outcomes. For example, a group may report lower annoyance scores from a transport source if authorities have undertaken a program of communication and explanation regarding the noise. Thus, studies where the intervention was designed to educate or change behavior, and studies that have measured intermediate outcomes of change in knowledge or attitude, will also be eligible for further consideration and synthesis.

However, we note that there will likely be many studies reported on noise management and control where the effect of an environmental noise intervention will not be reported as any of a change in health outcome, a change in exposure, or a change in behavior, but instead as a change in level of noise at or near the source. For example, the effects of motor vehicle source limit regulations, or of limits on aircraft noise emission resulting from certification requirements, are likely to be reported as changes in noise levels emitted by these sources over time. Or the effect of a path intervention through construction of a noise barrier near a roadway may be reported as the change in level immediately behind the barrier – not as a change in exposure levels for some affected population. Similarly, after an intervention involving modification to airport flight paths, the effect may be reported as changes in noise levels at particular points on the ground – again not as a change in exposure levels for some affected population. Studies that report these types of outcomes only cannot be utilized to understand the relationship between interventions and their health consequences.

4 OTHER CONSIDERATIONS REGARDING EVALUATING OUTCOMES FROM ENVIRONMENTAL NOISE INTERVENTIONS

We list below a range of additional matters that may need to be considered in future evaluations of the health outcomes of environmental noise interventions. They are more systems-wide issues to be taken into account to fully evaluate the effects of environmental noise interventions:

- a) Spatial scales of interventions and effects will vary from highly local (e.g. noise barrier on a particular roadway) to regional, national (emission limits for motor vehicles) or international (e.g. emission limits for aircraft).
- b) There may be lag times between interventions (e.g. regulations specifying vehicle limits which might take years to implement, or which rely on natural turnover in the vehicle fleet) and measurable effects.
- c) Some interventions are applied for short periods (e.g. temporary flight path changes) vs permanent interventions.
- d) Interventions may result in unintended displacement outcomes – for example a traffic restriction intervention that forces traffic into surrounding areas may introduce higher exposures in other areas even though, at the point of application, the exposures may be reduced.
- e) There may be subgroup differences in health outcomes from an area-wide intervention (e.g. effects on different socio-economic subgroups) and interventions that redistribute exposures across different areas need to be cognizant of differential SES of populations in these different areas.

- f) There may be effects on human health responses to noise generated by interventions in other fields (e.g. intervention with respect to traffic congestion).

5 CONCLUSIONS

A conceptual framework has been developed as a tool for further analysis of evidence, arising from a planned systematic search of the literature, of the relationship between environmental noise interventions and human health outcomes. The model will provide a framework for organizing a synthesis of the impacts of environmental noise interventions on human health which will be performed in the context of an update of the Guidelines for Community Noise (WHO, 1999). We have identified five broad categories of intervention which apply at various points along the system pathway between sources and outcomes. Categorisation is necessary as synthesis of evidence may only be appropriate when conducted across studies that belong to the same intervention category.

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