

Indicators of Environmental Health in the Urban Setting

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THE URBAN ECOSYSTEM AND HUMAN HEALTH

Today, the built environment is the most significant human environment. Globally, half of humanity now lives in urban settlements, while Europe and North America is 80% urbanized. These urban settlements have a disproportionate impact on the natural environment, consuming 75% of the world's resources and producing most of its waste.¹

In North America, humans spend approximately 90% of their time indoors and a further 5% in cars, leaving only 5% of the time when they are outdoors.² And since they are 80% urbanized, this means that much of the time spent outdoors is nonetheless spent within the confines of the built urban environment. The amount of time that North Americans spend outdoors in a natural (or mainly natural) environment may be as little as 1%.

The urban settlement can be viewed as a human ecosystem – an ecosystem largely created by and inhabited by humans and consisting of both the built and human-modified physical environment and the social, economic, cultural and political environments that humans have created. As such, an urban ecosystem can be identified as a dynamic complex of human, plant and animal communities situated within a given urban environment (based on IDRC's definition of an ecosystem in its "Ecosystem approaches to human health" program - www.idrc.ca).

It is also important to recognize that these human-created urban ecosystems exist within a larger frame of reference – the bio-regional and ultimately planetary natural ecosystems. While much of humanity may spend the majority of their time indoors and in an urban setting, it is natural ecosystems, not urban ones, that constitute the fundamental life support systems for humanity. The social and economic development that has been at the root of improved population health, first in the industrialized world and now globally, is built upon those natural ecosystems, their resources and the "free" eco-services they provide. Human health cannot be maintained if ecosystem health is not sustained.³ Any selection of indicators of environmental health in the urban setting must reflect

ABSTRACT

The North American population is approximately 80% urbanized and spends almost 90% of the time indoors. Accordingly, the built environment is the most important – one might almost say "natural" – human environment. Urban settlements incorporate within their boundaries natural ecosystems of plant and animal life (often highly adapted to the urban environment), and are in turn incorporated within wider bioregions and global ecosystems. But urban settlements are not just built and natural physical environments, they are social, economic, cultural and political environments; the whole constitutes an urban ecosystem. These ecosystems have profound implications for the physical, mental, social, emotional and spiritual well-being of their human inhabitants, as well as for human beings remote from these urban ecosystems. Therefore, this paper discusses urban ecosystems and human health and presents a framework for indicators of environmental health in the urban setting based on such an understanding. The concepts of environmental viability, ecological sustainability, urban livability, community conviviality, social equity, and economic adequacy are discussed in relation to human health and are used to organize proposed candidate indicators for urban ecosystems and public health.

RÉSUMÉ

En Amérique du Nord, environ 80 pour cent de la population vit en milieu urbain et passe presque 90 pour cent du temps à l'intérieur. En conséquence, le milieu bâti est le plus important environnement humain – on pourrait presque dire de lui qu'il est « naturel ». Les milieux urbains comprennent des écosystèmes naturels de plantes et d'animaux (souvent fortement adaptés à l'environnement urbain) et font aussi partie de plus grandes régions biogéographiques et d'écosystèmes planétaires. Cependant, de tels milieux sont non seulement des milieux bâtis et des environnements naturels et physiques, mais ils constituent aussi des milieux sociaux, économiques, culturels et politiques, dont l'ensemble forme un écosystème urbain. Ils sont intimement liés au bien-être physique, mental, socio-émotionnel et spirituel des habitants ainsi qu'à celui des humains qui vivent loin de ces milieux. L'auteur traite donc d'écosystèmes urbains et de santé humaine et présente un cadre pour des indicateurs de l'hygiène de l'environnement en milieu urbain qui est basé sur ces considérations. Il analyse les concepts de viabilité de l'environnement, d'écosystèmes durables, d'habitabilité des milieux bâtis, de convivialité des collectivités, d'équité sociale et de cadre économique adéquat en rapport avec la santé humaine et s'en sert pour organiser les indicateurs potentiels de santé publique dans des écosystèmes urbains.

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and incorporate these complexities and relationships.

Urban ecosystem health

Just as the health of natural ecosystems is measured in part by the health of the diverse microbial, plant and animal populations of which they are composed, and the level, quality and extent of the dynamic processes of the ecosystem, so too can the health of the human ecosystem be assessed in terms of the health of its population and the level, quality and extent of its dynamic social and natural processes.

Urban health thus has at least four distinct meanings:

- the health of the urban settlement in terms of the quality of its built environment;
- how well it functions socially as a community;
- how it functions biologically as an ecosystem (including the health of the biotic community of plant and animal life within and beyond the urban ecosystem); and
- the health status of the human population that lives within the urban ecosystem.

This suggests at least six dimensions to the concept of urban ecosystem health:⁴

- 1) the quality of the urban physical environment (air, water, soil);
- 2) the quality of the built environment;
- 3) the impact of the urban ecosystem on the wider natural ecosystems;
- 4) the health of the urban community as a social entity;
- 5) the health of the biotic community;
- 6) the health status (physical, mental, emotional and spiritual) of the urban human population.

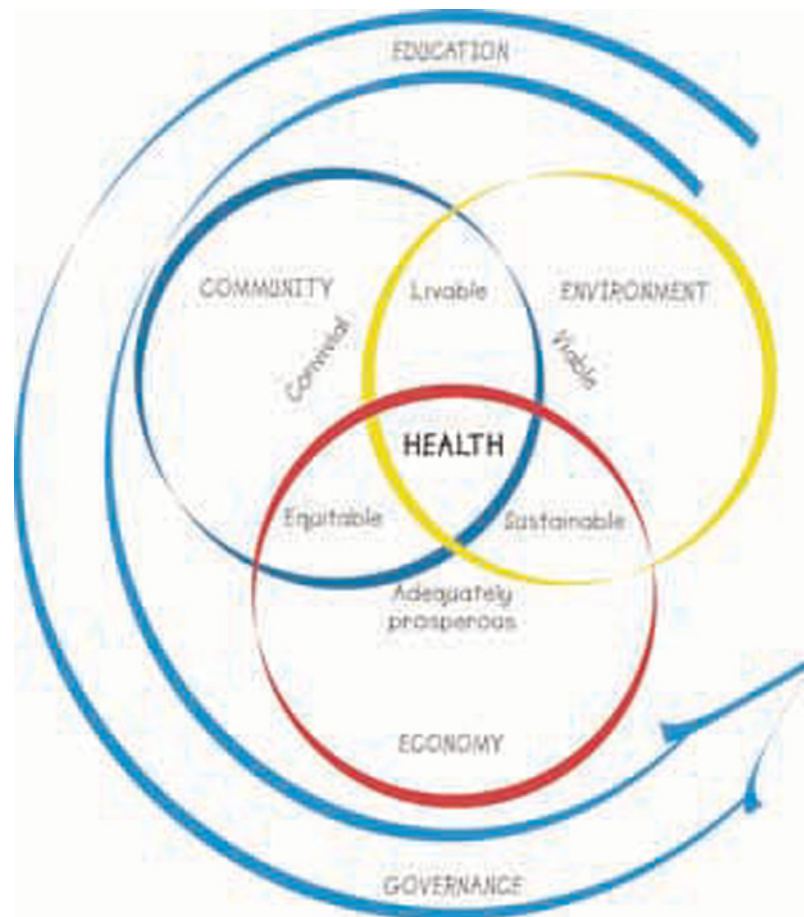
A framework for indicators

The model shown in Figure 1 is based on a healthy community model that has been in use for approximately a decade⁵ and that has recently been expanded.⁶ The basic framework links community sustainability and well-being (community, environment and economy) while paying attention to the links between these three spheres. It also focuses attention on the desired outcome – health – at the centre. The three spheres and their overlaps describe six qualities of a community that contribute to health:

Figure 1. Healthy Community Model⁶

- **Environmental viability:** the quality of the community's local environment;
- **Ecological sustainability:** the impact of the community on the wider bioregional and planetary ecosystems;
- **Urban livability:** a high quality built environment that is safe, pleasing and encouraging of conviviality;
- **Community conviviality:** concerned with the community's social well-being;
- **Social equity:** even distribution of power, resources and the benefits of the economy, and all members are treated with fairness and justice;
- **Economic adequacy (or well-being):** having a level of prosperity sufficient to ensure that basic needs for all are met.

The two key drivers of processes of change that have been added to the model are education and governance. These elements, when in place and working well, independently enhance human health as well as increase the likelihood that individual, community and political decisions in the three spheres and their overlapping areas of concern will result in the outcome of improved health.



INDICATORS OF HUMAN AND URBAN ECOSYSTEM HEALTH

This paper uses the indicator sets developed by Hancock, Labonte and Edwards⁶ as a starting point in proposing a set of indicators that can measure the six identified components of urban ecosystem health, the processes that influence it, and the outcome in terms of human and biotic community health. These indicators are organized based on the model (Figure 1) and the OECD's pressure/state/response framework.

"Pressure" indicators

These are indicators of the determinants of health for the biotic and human communities.

Viable Urban Environments and Health

In this context, a viable urban environment is one that does not poison or otherwise harm or kill either the human or the biotic communities of the city. This requires clean air, water, soil and food.

Outdoor air quality is a persistent problem in almost all major cities, due to pollutant emissions from energy generation, industrial, commercial and residential activity and transportation emissions. Ground-level ozone, particulate matter (especially PM_{2.5}), acid aerosols and air toxics (e.g., benzene and PAHs) are the main pollutants of concern, although the long-range transportation of many of these pollutants, heavy metals and persistent organic pollutants (POPs) is also a significant problem. Indoor air quality is a growing concern as well, especially since most urban dwellers today spend the vast majority of their time indoors. Key indoor contaminants of concern include NO_x, VOCs, environmental tobacco smoke (ETS), carbon monoxide and moulds.

Water pollution from human or animal excreta and chemical wastes is a major problem. While the vast majority of urban dwellers in the developed world today have access to a safe supply of piped drinking water, for those who do not, provision of safe piped water supplies remains a priority and its absence can result in infectious diseases as well as conditions arising from chemical contamination, including contamination resulting from water treatment itself (e.g., ref. 7). In addition to drinking water, urban dwellers have a need for recreational waters for swimming, fishing, boating and other activities. Microbiological pollution of beaches and rivers directly threatens the health of bathers and indirectly threatens the mental and social well-being of many others by denying them a valuable recreational resource. Further, chemical or heavy metal contamination may make hazardous the consumption of fish caught by both commercial and recreational fishers.

Soil pollution in cities is primarily linked to contaminated dustfalls from industrial sites (e.g., lead from smelters) and spills, leaks and other sources of contamination from current or old industrial sites. These tend to be localized conditions but the affected populations, as usual, tend to be the poorer sections of the communities living in close proximity to these sites. Children are particularly vulnerable due to their increased exposure to contaminated soils and housedusts, while all segments of the population – but especially women of child-bearing age – may be at risk from

vegetables grown in the contaminated soils of their local community.

Urban communities are not only recipients of pollution from elsewhere, they are also significant contributors to local, regional and global pollution. The extent to which the city produces both toxic products and toxic wastes is a measure of the viability as well as the sustainability of the urban ecosystem.

Potential indicators of viable environments are presented in Table I.

Sustainable Urban Environments and Health

In order to ensure the health of future generations of its citizens, a healthy city must also be environmentally sustainable. Ideally, this would mean that the city could meet all of its resource needs and handle all of its wastes within its own confines, or at least within its own hinterland. But given the size of modern cities, and given that their hinterland now encompasses much of the world, this is neither feasible nor realistic.

For our purposes, at the very least, a sustainable city should be reducing its contribution to the four forms of global change that affect human health (as noted by Davies and Hancock)⁸: climate and atmospheric change, pollution and ecotoxicity, resource depletion, and loss of habitat and biodiversity. It should know what its ecological footprint is and be attempting to reduce both its total and per capita impact on the ecosystem.

Energy use and conservation is an area of common concern, both because of the local and downwind air pollution resulting from combustion of fossil fuels and because of the release of huge quantities of CO₂. The health effects of global warming are likely to be very significant, even if remote in time and difficult to quantify at present.^{9,10} Thus efforts to reduce energy consumption and CO₂ emissions are likely to be beneficial to human health.

Efforts to improve energy efficiency in the heating of buildings may also have beneficial health effects. However, because indoor air pollution can be increased by sealing buildings more tightly and reducing the intake of fresh air, it is important to strike a balance and to use new approaches such as “green” or naturally ventilated buildings to reduce heating and

cooling requirements, as well as reducing the use of toxic materials in the construction, furnishing and operation of buildings.

In addition to contributing to climate and atmospheric change, urban environments contribute extensively to pollution and ecotoxicity, use both renewable and non-renewable resources, and contribute to the loss of habitat and biodiversity. Among the renewable resources that cities deplete are fresh water, farm lands (both by paving them over with urban sprawl and by their heavy demand for food, which can often only be met through unsustainable farming practices), forest products (notably lumber and paper) and fisheries. Also, cities consume huge quantities of non-renewable resources such as fossil fuels, metals and minerals. An assessment of the per capita consumption of these key resources and of loss of habitat and biodiversity is an important measure of the sustainability – or unsustainability – of an urban ecosystem.

Potential indicators for the environmental sustainability of urban ecosystems are presented in Table I.

Livable Urban Environments and Health

Livability has a great deal to do with social as well as physical conditions and the interplay between those two elements in the “settings” within which people lead their lives.¹¹ At its most basic, livability refers to the quality of the housing stock and such fundamental physical infrastructure as water and sewage supplies, roads and public transportation systems and other infrastructure that make it possible for people to lead healthy lives and access the city’s amenities and services. An important aspect of livability is the extent to which noise, litter and dirt make the urban environment unpleasant, even stressful and harmful to health.

Livability also refers to how safe the community is, in terms of the prevention of accidental injuries arising from unsafe housing and other buildings, transport-related accidents, and other sources of fires, explosions, leaks and spills, and various forms of crime. Further, the very important issues of traffic and urban design which influence urban health must be considered here as well. Traffic contributes to health problems (e.g., air pollu-

tion) and detracts from many aspects of conviviality, and urban design must incorporate such things as the need for equitable access to, and efficient operation of public transportation.

Livable environments move beyond meeting the basic needs and defensive measures intended to ensure safety and security to look at ways in which the built environment can be a lively, diverse, stimulating, aesthetically pleasing environment which, in turn, help create an environment that promotes health and well-being.

Potential indicators of livable environments are presented in Table I.

Convivial Urban Environments and Health

In a convivial community, people live well together, they provide social support, they address problems and settle differences amicably, they participate fully in the life of their community. Such communities have high levels of social capital¹² and social cohesion. Such conviviality results from both the informal social networks that make up the community and from the formal social support system provided by the state in the form of social security and human services. One aspect of place-based social support is a sense of neighbourliness and a sense of neighbourhood or place, which is a factor in both “community resilience” and “community competence”, both of which are associated with improved health status.¹³

Potential health indicators in this area are presented in Table I.

Equitable Urban Environments and Health

Inequalities in health, wealth, power and resources are inherent in the human condition. Some of those inequalities are relatively fixed, rooted as they are in biological differences such as gender, age, genetic inheritance and so on. But many other inequalities are rooted in inequitable (unfair or unjust) access to wealth, power, resources and other determinants of health. Reductions in inequalities in health that are rooted in such inequitable circumstances are dependent upon addressing social and economic inequity.

The results of such factors as social, economic and environmental injustice (e.g., the poor live downhill, downwind or

TABLE I

Suggested Indicators of Urban Ecosystem Health (* = possible key indicators)

General	Specific Examples
Viability Outdoor air quality* Indoor air quality Drinking water quality* Recreational water quality* Contaminated sites* Production of toxic* –products –wastes Food chain contamination*	O ₃ ; PM ₁₀ ; PM _{2.5} ; acid aerosols; air toxics ETS; VOCs; NO _x ; Microbial and/or chemical Fecal pollution of near-shore recreational waters # of contam. sites/100,000 Pesticide production, other? Toxic wastes – which ones? Dioxin/other POP/heavy metal dose in a standard food basket or Chemical contaminant in edible fish tissue
Sustainability Energy use* –fossil fuel use* CO ₂ /GHG emissions* Resource consumption –renewable –non-renewable Ecological footprint*	Total energy use/capita Total fossil fuel use/capita Total and per capita emissions Fresh water, wood, agricultural land, fish, etc. (consumption/capita) Fossil fuels, metals, minerals Total and per capita
Livability Environmental hygiene Housing quality* Hygiene Noise Community safety Road quality Fires, explosions, leaks and spills* Crime rates*	Fitness for human habitation, Building/Safety Code violations Litter, waste management Noise levels, complaints MVAs due to poor road quality –# of occurrences, # of people affected Violent crimes, sexual assault, robbery, etc., as well as fear of crime, feeling of safety
Traffic Traffic management Public transportation* Pedestrian-friendly Urban design –appeal/pleasing –diverse/stimulating	Traffic calming, traffic-free areas, etc. Modal split, accessibility Walkability Index
Conviviality Social support –social networks –formal social support services –sense of place/neighbourhood	
Prosperity Diverse economy Quality of workforce and Quality of Work Life ‘Green’ business* Economic activity	Proportion of workforce in top 10 employees QWL indicators “Green” business as % of total, or # of start-ups GPI
Biotic Community Status Presence, number and diversity of key species* Health of ecosystems such as wetlands* Health of key indicator species* Contaminant levels at top of food chains*	Reproductive success, congenital anomalies, cancer Key POPs in raptors, pike, humans, etc.
Human Health Status (see Table II) Mortality Morbidity Positive health	
Information Data collection systems* Data available to the public*	
Education/awareness School curriculum* Media content*	
Citizen involvement Number of community groups Status and role of community groups “Round Tables”*	
Government decisions Commitment of resources* Presence on Council agendas Legislative measures	

downstream) can be found in the inequalities in health status that exist within and between urban ecosystems. The implication for indicators of environmental health is that we need indicators that can identify inequity in general and environmental and health inequities in particular.

Such indicators include

- economic disparity (e.g., levels of poverty, hunger, homelessness and access to affordable housing);
- measures of social discrimination and exclusion from services, resources and power;
- indicators of environmental injustice (e.g., proximity to industrial or waste sites);
- health status measures that can be disaggregated on a geographic and social basis to identify and highlight inequalities.

Urban Prosperity and Health

Jane Jacobs¹⁴ has argued that cities are the economic engines and the true generators of the wealth of nations. Urban ecosystems must generate enough wealth to ensure that the fundamentals of good health such as safe water, food, environmental hygiene, safe disposal of wastes, universal education and other basic human services, and the fundamental processes of governance can be ensured for all. Beyond that, two important measures of the urban economy are its diversity and adaptability. The latter quality is dependent in part upon the quality of the workforce, as well as the adequacy of the (lifelong) education and the human resource development policies of the city and its public and private sectors.

One important new dimension of urban economies that is of enormous significance for the environment and health is the extent to which local businesses are environmentally responsible and, even more profoundly, the extent to which new “green” businesses are developing. New measures of economic output such as the Genuine Progress Indicator or GPI,¹⁵ which attempt to both exclude environmentally, socially and health damaging economic activities and include a variety of non-monetized socially beneficial activities (such as child rearing, volunteer work, growing one’s own food, etc.), provide an accurate and useful guide to the true “wealth” of a city and should be included here.

Proposed indicators of these issues are presented in Table I.

“State” indicators

Indicators of the status of the urban ecosystem fall into two categories which can be considered as the output of both the determinants of health (pressure indicators) and the effectiveness of the processes of governance (response indicators). The two output or state indicator categories are the health of the biotic community and the health of the human population.

Biotic Community Status

The urban ecosystem contains within it a vast range of living organisms. The health of this biotic community and its organisms is a reflection of the viability of the urban ecosystem, and the overall health of the urban ecosystem and its suitability as a habitat for humans. A wide variety of indicators of biotic community health are available and some are listed in Table I (for more examples, see www3.ec.gc.ca/cehi/en/indic_e.htm).

Human Health Status

From an anthropocentric perspective, human health status is the ultimate measure of success. One of the challenges we face is making clear and explicit links between environmental problems and human health. Nonetheless, a number of health outcomes related to key environmental factors in urban ecosystems can be proposed and these are shown in Table II. These fall into the categories of mortality (e.g., respiratory diseases related to outdoor and indoor air pollution), morbidity (e.g., food-borne infectious diseases), and positive health measures (e.g., self-reported health and life satisfaction).

“Response” indicators

Faced with evidence of damaged or threatened environments or evidence of actual, perceived or threatened harm to human health, cities and societies respond. Both pro-active and reactive responses are aspects of our processes of governance. The making of choices and decisions depends upon a number of factors as discussed below. Potentially key response indicators at a general level are listed in Table I.

Information

It is essential that there is an information system in place that can collect the requisite data on a routine basis, link that data

to other information systems and present the data to the public and to decision-makers. One important, and often limiting, challenge is that data are often not easily available routinely at the city level. Even when they are, it is even less likely that the sampling method and sample size regularly allow for disaggregation to the neighbourhood level.

Education and Awareness

Perhaps the most important prerequisite for action on environmental health hazards is public awareness of the issues, which fuels public concern and social and political action. Such awareness needs to begin in school; in the 21st century, children need to have a full and broad-based understanding of local and global environmental issues and of the importance of ecosystem health as the underpinning of social and economic development. Not only do these children grow up to be environmentally aware adults, they also help to raise the environmental awareness of today’s adults.

A second key component of environmental awareness is the attention paid to this subject by the media. The extent to which local and national print, radio, TV and e-media cover environmental issues and the relative importance – as well as any ‘bias’ they display – are important indicators.

Citizen Involvement

While the key to an active citizenry is information, education and awareness, that awareness has to be translated into action. Concerned citizens, acting as individuals, as community groups or through environmental NGOs, have played a crucial role in addressing environmental issues both locally and globally. Citizen involvement in environmental issues is one important aspect of a civil society.

Governance

Governance is the process by which we as a society or a community make choices and decisions. This process involves not only the government but a wide array of other stakeholders that constitute a civil society, including business, citizen groups and NGOs, labour, the charitable sector, etc. One measure of the process is whether or not there is a forum (or several fora) that bring together these often competing inter-

ests in an attempt to find consensus and a common approach.

Ultimately, the test is whether, as a result of this process, local, state/provincial and federal governments give environmental health the priority it deserves. This is shown through their commitment of resources, the passage of legislation and the enforcement of such legislation.

PROPOSED INDICATORS

The biggest challenge in developing indicators is to select from the many hundreds if not thousands of potential indicators that are available. For the purposes of this exercise, the indicators set for urban ecosystem and health must include measures of:

- exposure to priority substances (air, water, soil, foodchains)
- urban living conditions (physical, social, economic)
- services and programs for health protection
- health effects (acute, chronic, physical, mental, behavioural)

at various scales, in particular to permit intra-urban comparisons (spatial and non-spatial). Of course, not every indicator can or should meet all of those criteria; rather the point is to select a battery of indicators that among them provide good coverage of these requirements (for a further discussion of indicators criteria, see Hancock, Labonte and Edwards,⁶ or Eyles and Furgal – this issue¹⁶). In an attempt to focus the list provided here, a set of potential “Key Indicators” are denoted with an asterix in Tables I and II.

Gaps in indicators

The biggest problem with many of these indicators will be their availability at the county or city level, and even more problematically at the neighbourhood level. This latter issue may make assessment of inequity in environmental, social, economic or health status terms difficult, if not impossible. Another problem may be the availability of an assessment of food chain contamination and the levels of POPs in the tissues of top predators and humans. Yet such data are essential if we are to assess and track the exposure of humans to these toxic substances.

Many other indicators suggested in Tables I and II were not considered for

TABLE II

Suggested Human Health Status (Outcome) Indicators (* = possible key indicators)

Determinant (Pressure) Indicator	Human Health Status (Outcome) Indicator
Outdoor air quality*	<ul style="list-style-type: none"> • Asthma and other respiratory or cardiovascular mortality and morbidity related to key air pollutants • Excess mortality and morbidity during pollution episodes
Indoor air quality	<ul style="list-style-type: none"> • Asthma, “sealed building syndrome”
Drinking water quality*	<ul style="list-style-type: none"> • Water-borne infectious disease mortality and morbidity (giardia, E. Coli, cryptosporidium, etc.)
Recreational water quality	<ul style="list-style-type: none"> • Outbreaks of G-I or skin infections or otitis externa
Toxic contaminants*	<ul style="list-style-type: none"> • Cancers linked to pesticides and POPs (e.g., childhood brain cancer, lymphomas, etc.) or to disinfection by-products (bladder cancer) • Tissue levels of key contaminants
Global warming	<ul style="list-style-type: none"> • Heat-related mortality • Insect-borne disease rates (e.g., malaria, dengue fever, encephalitis, etc.)
Unsafe/poor quality housing*	<ul style="list-style-type: none"> • Mortality and morbidity from fires, accidents, etc., related to unsafe housing • Anxiety, stress, depression due to poor housing
Roads/transportation*	<ul style="list-style-type: none"> • MVA mortality and morbidity
Toxic fires, spills, leaks and explosions*	<ul style="list-style-type: none"> • Mortality and morbidity associated with such incidents
Crime*	<ul style="list-style-type: none"> • Mortality (homicide) and morbidity due to assault, sexual assault, robbery with violence, etc. • Fear of crime, violence; not feeling safe
Noise*	<ul style="list-style-type: none"> • Sleep disturbance or other stress due to noise
Social support*	<ul style="list-style-type: none"> • Anxiety, depression secondary to loneliness, isolation
Environmental injustice*	<ul style="list-style-type: none"> • Inequalities in mortality and morbidity linked to environmental causes
Quality of working life	<ul style="list-style-type: none"> • Mortality and morbidity related to occupational injury and disease • Workplace stress, satisfaction with work life

inclusion in the list of key indicators, whether because they are not routinely collected, because there is no generally agreed-upon measure, or because the relationship between environmental conditions and health status is not well established.

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