How Much Disease Burden can be Prevented by Environmental Interventions?

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Abstract: There is very little systematically collected evidence on the overall contribution of environmental risk factors to the global burden of disease. The World Health Organization (WHO) recently completed a comprehensive, systematic, and transparent estimate of the disease burden attributable to the environment highlighting the full potential for environmental interventions to improve human health.

This report is the result of a systematic literature review on environmental risks completed by a survey of expert opinion using a variant of the Delphi method. More than 100 experts provided quantitative estimates on the fractions of 85 diseases attributable to the environment. They were asked to consider only the contributions of the "reasonably modifiable environment"—that is, the part of environment that can plausibly be changed by existing interventions.

The report estimates that 24% of the global burden of disease was due to environmental risk factors. Environmental factors were judged to play a role in 85 of the 102 diseases taken into account. Major diseases were, for example, diarrheal diseases with fractions attributable to the environment of 94%, lower respiratory infections with 41%, malaria with 42%, and unintentional injuries with 42%. The evidence shows that a large proportion of this "environmental disease burden" could be averted by existing cost-effective interventions such as clean water, clean air, and basic safety measures. In children, 34% of the disease burden is attributable to the environment, and much of this burden is in developing countries.

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Environmental health action can improve population health in a sustainable manner and improve equity. Such action can also make a major contribution toward achieving 6 of the 8 Millennium Development Goals and thus may be a prerequisite for their success.

The role of environmental management in improving health has been neglected in recent years. This neglect is partly due to competition for resources and policymakers' attention from more immediately obvious health threats arising from, for example, the HIV/AIDS pandemic. It also results from the perceptions that environmental risk factors have only a relatively small impact on the global burden of disease and that investments in environmental management have low cost-effectiveness in comparison with other health interventions.

In reality, there is very little evidence to support these perceptions. Although the role of environmental interventions in disease prevention has been assessed for selected risks and diseases, until recently, there has been no systematic and consistent assessment of the global burden of disease resulting from environmental risk factors or of the effectiveness or cost-effectiveness of these interventions.

The WHO has now completed a study designed to estimate the disease burden attributable to the environment to address the full potential of environmental interventions to improve human health.[1] This study was based on a 6-year process to quantify how much disease can be attributed to various environmental risks. In this commentary, we describe the methods used to arrive at these estimates, and we summarize the key findings. We present a systematic review of the literature for quantitative assessments of population health impacts from environmental risks with information gaps completed by quantitative estimates from experts in the relevant fields. We provide attributable fractions and global disease burden due to the environment for every considered disease and injury category, and we outline the areas where environmental interventions are likely to bring the greatest health gains. Full details of this analysis are provided in the comprehensive publication.[1]

Previous estimates of the global burden of disease due to the environment were 23%[2] and 25% to 33%[3]; for countries of the Organisation for Economic Co-operation and Development (OECD), the estimate was 2% to 5%.[4] Furthermore, the WHO recently coordinated the Comparative Risk Assessment, which quantified the health impacts of 26 major risks, 6 of which were environmental, using a comparative framework.[5,6] We based our work on these previous studies and further improved or completed them by: 1) enlarging the

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scope to include most of the risks contained in the environment (eg, 8 other major risk factors in addition to the 6 explored in the Comparative Risk Assessment as well as the work environment, which had not been included in the OECD study); 2) systematically reviewing 102 diseases and injuries as to their environmental causes (eg, the Comparative Risk Assessment reviewed 42 diseases for selected environmental causes but covered the majority of environmental causes of only 2 diseases); 3) consulting experts to complete gaps in the evidence to obtain a more comprehensive estimate of the potential of healthy environments to prevent disease; and 4) limiting the environment to only the "reasonably modifiable environment" to improve the policy relevance of results. In this review, more than 100 experts throughout the world were consulted to provide attributable fractions of 83 diseases and 2 risk factors (physical inactivity and malnutrition), providing a substantially greater coverage than achieved in previous systematic reviews such as the Comparative Risk Assessment. The experts are all listed in the full report[1] and their contribution is gratefully acknowledged.

WHAT IS THE ENVIRONMENT? WHAT CAN BE PREVENTED?

To be relevant to policy, the definition of environment used in this study was "the physical, chemical and biologic environment to the human host and related behavior, but only those parts that could reasonably be modified," ie, that which can be altered with existing interventions and without impairing other ecosystem functions.

This definition included risks such as the pollution of air, water, and soil; ionizing radiation; noise; occupational risks; the built environment, including housing and road design; land use patterns; agricultural methods and irrigation schemes; and manmade changes to the climate and ecosystems. To illustrate the work environment, infections acquired during occupation such as from needlestick injuries in healthcare workers, or sexually transmitted diseases among commercial sex workers, are included. Behavior related to environment was included such as lack of hand-washing related to the availability of sanitary facilities that could lead to the contamination of food. Although ultraviolet radiation per se cannot be acted on (other than through manmade atmospheric changes), its effects were included, because they can be modulated by personal protection behavior.

Excluded from the definition are alcohol and tobacco consumption; diet; natural environments that cannot reasonably be modified such as rivers, lakes, and wetlands; and natural biologic agents such as pollen in the outdoor environment. The social environment and behaviors not specifically related to the environment (eg, unemployment, cultural pressures, and so on) were also excluded from the working definition. However, some aspects of the social environment could overlap with the physical environment but were not included here. Examples include advertising and the absence of healthy food choices, which lead to a diet of low-quality food. Although the more distal economic and social determinants of occupational conditions such as job security are in principle included in the definition, they could to a large extent not be assessed here.

The attributable fraction is the proportional reduction in disease or death that would occur in an exposed population if exposure to a risk were reduced.[7,8] In this analysis, the environmental risks were reduced, not to zero, but rather to a baseline exposure (or counterfactual) that was "reasonably achievable" in the short or medium term. Many diseases can be prevented by reducing several different risks, and the attributable fractions for the risks could in such a case sum to greater than 100%.[9]

ESTIMATION OF ATTRIBUTABLE FRACTIONS

For each of the 102 diseases and injuries listed in the WHO global disease statistics for the year 2002,[10,11] the literature was systematically reviewed to compile summaries of the best available evidence of population health impacts from environmental risks. The search terms included each disease or injury (listed in Table 1) and "environment" or any of the relevant environmental risks or occupational groups at risk. Medline was searched for the last 20 years, and additional articles and reports were handsearched based on the reference lists of main publications or lists provided by experts consulted in this survey. When available, specific databases were searched (ie, AIDS epidemic update, HIV/AIDS surveillance database).[12,13]

For each disease or injury, the identified literature was selected in the following order of priority: 1) global estimates for selected environmental risks (such as Comparative Risk Assessment[5,6]); 2) estimates of population health impacts at the regional or national level; 3) meta-analysis or reviews on disease reduction from environmental interventions or determinants of health; and 4) individual studies of interventions and determinants of health. Summaries of the best available evidence according to these criteria were then prepared and submitted to at least 3 experts who were asked to provide their estimates of fractions attributable to the environment for one or more diseases or injuries (or their groupings). Diseases, injuries, or their groupings were classified according to the International Classification of Diseases.[14]

Experts were selected on the basis of their international reputation in the area of disease or the relevant environmental risk factor. For balance, experts from across the globe were sought, particularly for diseases that showed strong geographic variation. They were asked to provide their estimate of the fraction attributable to the reasonably modifiable environment (best estimates and 95% confidence intervals [CIs]) on the basis of the summary evidence for the disease or injury category of their expertise. Experts were also given the option to provide estimates by sex, age group, or region.

The expert replies were assumed to have a triangular distribution defined by the best estimate and 95% CI they provided. For each disease or injury, the probability distributions from individual experts were combined by summing the probabilities at each value of attributable fraction.

We used the following equation to calculate the probability distribution of attributable fractions:

$$P_{(AF)} = \sum_{K=1}^{n} P_{(AF)}$$

TABLE 1. Main Areas of Environmental Interventions for Diseases and Injuries*

Disease or Injury†	Main Environmental Intervention Areas
Respiratory infections	Indoor smoke from solid fuel use[16] Outdoor air pollution[5,17] Environmental tobacco smoke[18] Housing (chilling, crowding)[19,20] (AF‡ for lower respiratory infections: 36% to indoor smoke from solid fuel use[5,16]; AF for respiratory infections: 1% to outdoor air pollution[5,17])
Diarrheal diseases	Drinking water quality, sanitation facilities, personal and community hygiene[21]; recreational water quality[22] Animal excreta management and agricultural practices[23,24] (AF: 88% to water, sanitation, and hygiene[5,21]; 2% to climate change[5,25])
Malaria	Environmental modification, including drainage, land leveling, filling depressions, contouring reservoirs; environmental manipulation, including vegetation management, safe storage of domestic water, managing peridomestic waste; reduced contact between humans and disease vector such as behavior change[26,29] (AF: 2% to climate change[25])
Intestinal nematode infections	Sanitation facilities and hygiene to prevent contamination of the environment with excreta[21]
Trachoma	Personal hygiene such as facewashing; fly control (such as window screens, waste management); sanitation facilities[30–34] (AF: 100% to water, sanitation, and hygiene)[21]
Schistosomiasis	Excreta management; safe water supply; irrigation, and other agricultural practices; worker's protection to avoid contact with contaminated water (such as wearing rubber boots)[21,27,35,36] (AF: 100%)[21]
Chagas disease	Management of peridomestic areas (such as filling cracks in house walls, clearing areas around houses of wood stacks, goat corrals, and chicken dens)[27,37–39]
Lymphatic filariasis	Modification of drainage and wastewater ponds, freshwater collection and irrigation schemes; impact depend on locally relevant disease vectors[40–42]
Onchocerciasis	Water resource management projects (particularly dams)[43]
Leishmaniasis	Housing conditions[44–49]
Dengue	Management of water bodies around the house such as removing standing water from open water containers and solid waste[50]
Japanese encephalitis	Management of irrigation areas and limiting their access to farm animals[51]
HIV/AIDS and sexually transmitted diseases	Occupational transmission in sex workers and migrant workers[12,13,52]
Hepatitis B and C	Occupational transmission in sex workers and migrant workers for hepatitis B[53–55] Accidental needlestick injuries in healthcare workers (AF: 0.3% for hepatitis B and C)[56]
Tuberculosis	Exposure of miners and other occupational groups to airborne particles such as silica or coal dust and workers handling asbestos[57–62] Conditions in settings such as prisons, housing, hospitals[63–70]
Perinatal conditions	Mother's exposure to environmental tobacco smoke, chemicals, air pollution[18,71–77]
Congenital anomalies	Mother's exposure to chemicals, radiation, air pollution[78–81]
Malnutrition	Water, sanitation, and hygiene[82–84]
Cancer, total	Exposure to chemicals,[85] outdoor and indoor air pollution,[16,17] environmental tobacco smoke,[86,87] ionizing radiation[88]; ultraviolet radiation[89] (exposures at work and other settings) (AF for lung cancer: 9% to occupation[90]; 5% to outdoor air pollution[17]; 1% to indoor smoke from solid fuels[16]; AF for other cancers: 2% to occupation[90])
Neuropsychiatric disorders[100]	Occupational stress has been linked to depression[91]; noise exposure to insomnia[92,93]; exposure to chemicals to Parkinson disease[94,95]; drug use and alcohol disorder to the occupational environment such as working in the entertainment or alcohol industry[96]; posttraumatic stress disorders to disasters such as floods, earthquakes, and fires, of which part could be prevented by environmental measures (eg, floods by dams, land use patterns or in the mitigation of climate change, or the impact of earthquakes and fires through more adequate building materials); epilepsy to occupational head trauma; mild mental retardation to childhood exposure to lead[5,97]
Cataracts	Ultraviolet radiation[89]
Deafness	Occupational exposure to high levels of noise[5,90]
Cardiovascular diseases	Stressful workplace conditions,[98–100] air pollution, environmental tobacco smoke,[101] lead[97] (AF for cardiopulmonary disease: 2% to outdoor air pollution[17]; AF for ischemic heart disease: 2% to lead[97]; AF to cerebrovascular disease: 3% to lead[97])
Chronic obstructive pulmonary disease	Exposure to dusts and chemicals in the workplace,[90] exposure to indoor[16] and outdoor air pollution[17] (AF: 22% to indoor smoke from solid fuels [16]; 12% to occupational exposure to airborne particulates[90]; AF for cardiopulmonary mortality from outdoor air pollution: 3%[17])

(Continued)