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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Editors' note: *Related articles appear on pages 162 and 179.*

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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

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:

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

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*)

TABLE 1. (*Continued*)

Disease or Injury†	Main Environmental Intervention Areas
Asthma	Indoor exposures to dust mites and fungal allergens,[4] possibly indoor smoke from solid fuels,[16] environmental tobacco smoke,[102,103]; exposure to outdoor air quality[102,104]; occupational exposure to allergens[90] (AF: 11% to occupational exposure to airborne particulates)[90]
Musculoskeletal diseases	Exposure to occupational risks for rheumatoid arthritis, osteoarthritis, and low back pain such as vibrations, repetitive trauma, knee bending, or lifting heavy weights[90,105–111] (AF: 37% of back pain to occupational ergonomic stressors)[90]
Road traffic injuries	Land use policies and practices; road design (such as segregated bicycle tracks or lanes alongside urban roads, the introduction of barriers along the roadside or pedestrian crossing signs[90,112-114]; urban structure and density; poor matches of road design and vehicles; street maintenance; traffic calming measures such as one-way streets, road narrowing, speed limits, street closures, or speed humps[112,115–118] (AF: 6% to occupation)[90]
Unintentional poisonings	Safe storage and handling of chemicals; adequate product information[119,120]
Falls	Safety of housing and work environment (including window guards or grab rails, removal of slippery surfaces, adequate lighting, good visibility)[112,121–124] (AF: 12% to occupation)[90]
Fires	Types of materials used to build housing, home design (such as fire alarms), types of home furnishings; in developing countries also use of unsafe stoves, open fires or kerosene candles in the house[118,121,123] (AF: 2% to workplace factors)[90]
Drownings	Safety of the recreational environment (physical barriers, prevention and rescue services), built environment (such as unprotected wells or house cisterns), floods, worker's safety (such as regulations); safety measures and regulations on transportation on waterways[125–127] (AF: 1% to occupation)[90]
Other unintentional injuries	Safety of mechanical equipment (including sports equipment and agricultural machinery), safety of off-road transportation, animal bites and contact with venomous plants; exposure to ionizing radiation or electric currents; natural forces (periods of excessively hot or cold weather, floods[10–14] (AF: 18% to occupation[90]; AF: 0.4% to floods caused by climate change[25])
Suicide	Access to guns, pesticides or other chemicals, toxic content of domestic gas[128–132]
Violence	Storage of firearms[133,134]; street lighting[135]; exposure to certain substances such as lead[136–140]
Physical inactivity	Environmental factors encouraging physical activity; includes factors in the built environment[141] such as land use mix and densities, access to key destinations and facilities, transport infrastructure, building design, sidewalks, ample building setbacks, walking and cycling paths, parks, bus shelters, streets that are easy to cross[142–148]; or policies facilitating more active lifestyles such as car-related taxes[149,150] NB: physical inactivity is a risk factor that is related to numerous diseases such as diabetes mellitus, breast cancer, colon cancer, ischemic heart disease, ischemic stroke[151]

*Global attributable fractions from the Comprehensive Risk Assessment are listed in parentheses.

†The 85 diseases and injuries with an environmental contribution are grouped into 35 categories; for further detail, see the full report.[1] Several diseases and injuries are in addition impacted by human-induced climate and ecosystem change such as malaria, dengue, diarrhea, cardiovascular diseases, unintentional injuries, and so on; main interventions include adaptation while limiting greenhouse gas emissions.[25,152–155]

where AF = attributable fraction, P = resulting probability at attributable fraction AF, p = individual expert probability at attributable fraction AF, and E = experts.

The resulting mean attributable fraction was defined as the overall best estimate. A new 95% CI was calculated from the combined probability distribution of the attributable fractions. An example for road traffic injuries in developing countries is given in Figure 1.

With this method, extreme estimates (or outliers) can lead to large CIs. For this reason, if an expert estimate did not overlap with any of the other expert estimates, the outlier point estimate was used to define the relevant boundary of the CI for the disease instead of using the CI from the expert. When no uncertainty intervals were specified for the Comparative Risk Assessment or other global estimates, ±30% lower and upper boundaries around the best estimate were used. No CIs were used when the attributable fraction was 100%. Confidence intervals for the summary statistics were calculated from the probability distributions for the attributable fractions using simulation techniques[15] and the software package @risk 4.5 for Excel (Palisade Europe UK Ltd., London, UK).

ESTIMATION OF DISEASE BURDEN ATTRIBUTABLE TO THE ENVIRONMENT

To obtain the global burden of disease due to the modifiable environment, the attributable fractions obtained in this study were multiplied by the relevant WHO global disease statistics for 2002[10,11] for each disease or injury, 14 subregions (see footnote of Fig. 2), age group, and sex, as shown subsequently.

The following equations were used to calculate attributable mortality and disease burden:

$$AM = AF \times M$$

and

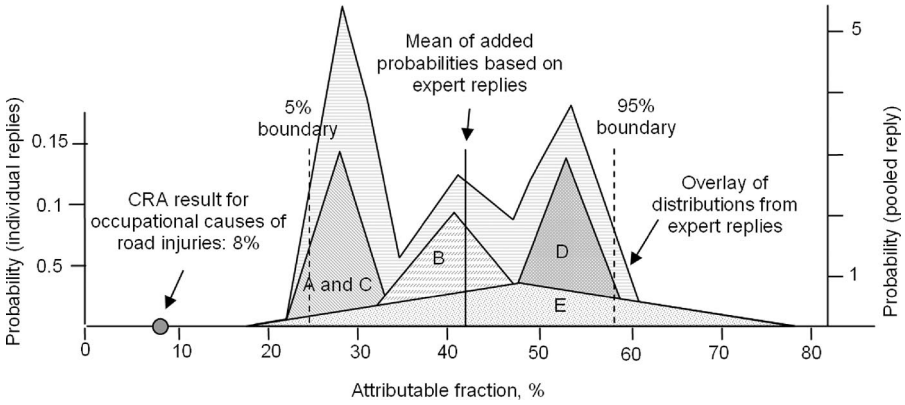

FIGURE 1. Road traffic injuries in developing countries. Distributions for 5 expert replies (A–E) and the resulting pooled estimate in comparison with the Comparative Risk Assessment partial fraction for occupation. The vertical lines show the mean and the 5% and 95% confidence boundaries of the summed probability distribution. The CRA result (8%) only partially captured the environmental contribution to traffic injuries, because it covered only occupational contributions.

$$AB\ (DALYs) = AF \times B\ (DALYs)$$

where AM = attributable mortality, M = mortality, B = disease burden computed as disability-adjusted life-years (DALYs), and AB = attributable disease burden in DALYs, stratified in regional, sex, and age groups when relevant.

MAIN FINDINGS OF THE REPORT

More than 100 experts provided approximately 200 quantitative estimates for the environment attributable fractions of diseases and injuries based on the systematic literature reviews. Of the 102 diseases and injuries listed in the WHO disease statistics,[10,11] 85 were considered to have environmental contributions. The earlier Comparative Risk Assessment study provided fractions attributable to selected environmental risks for 42 diseases or injuries, but all major environmental risks were addressed for only 2 categories (ie, low back pain and hearing loss). Experts were therefore consulted to provide estimates of attributable fractions for 83 diseases or injuries and 2 risk factors (physical inactivity and malnutrition). A minimum of 3 and maximum of 11 experts provided quantitative estimates for each disease or injury category. Most experts provided estimates for only one disease or injury, but some had expertise in several categories.

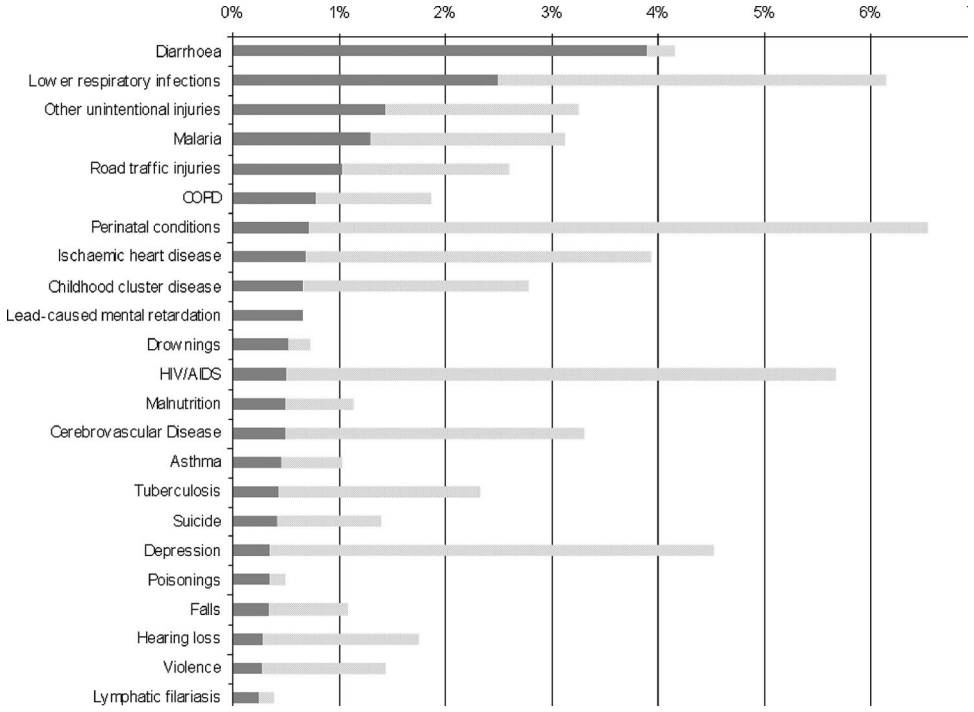

FIGURE 2. Diseases with the largest environmental component. For each disease or injury, the environmental contribution to the global disease burden (dark bar) is shown in comparison with the nonenvironmental contribution (light bar). Data are for the year 2002. COPD indicates chronic obstructive pulmonary disease.

The main areas of potential impact of environmental interventions are summarized in Table 1, and further details on the linkages between diseases and environmental risks are given in the full report.[1]

The fractions attributable to the environment as determined in the WHO study, as well as the resulting disease burden in deaths and DALYs, are summarized in Table 2 by disease and injury. Regional and age-specific results are provided in the full-text document.[14]

Environmental risks contributed 24% (95% CI = 21–27%) to the global burden of disease measured in DALYs and by 23% (21–25%) to all deaths. The diseases with the largest environmental contributions globally are displayed in Figure 2 for the year 2002. Together, the 5 diseases with the largest contributions—diarrhea, lower respiratory infections, other unintentional injuries, malaria, and road traffic injuries—were responsible for more than 10% of the global burden of disease (in DALYs). The environmental attributable fractions varied widely across regions (Fig. 3). Children carried a disproportionate share of the disease burden; in children 0 to 14 years old, environmental attributable fractions of all deaths were as high as 36% (31–40%).

Diarrheal diseases, lower respiratory infections, neuropsychiatric conditions, and cardiovascular diseases are the largest contributors to global disease with an environmental component. These diseases together accounted for more than one third of the disease burden from environmental risks. Diarrheal diseases and lower respiratory infections mostly affected children in developing countries, whereas neuropsychiatric disorders and cardiovascular diseases mainly affected adults in both developed and developing countries.

CONCLUSIONS AND IMPLICATIONS

The WHO report provides a systematic and comprehensive estimate of how much of the global burden of disease can be prevented by environmental management. Only the reasonably modifiable environment was taken into account; therefore, the joint evidence from interventions studies and expert estimates indicate the potential burden of disease that could reasonably be prevented by environmental interventions. The study represents a comprehensive estimate, because all major diseases and environmental risk factors were included. It adds to previous compilations of evidence[2–6] and presents results in terms of mortality and a common metric (DALYs).

A limitation of the study is the lack of the type of evidence that is available from other areas of public health such as treatment of disease. This lack leads to larger uncertainties, and the evidence may be improved as new studies emerge. Nevertheless, this is the best available evidence and provides decision-makers with indicative information as to where environmental modification has the greatest potential to alleviate the burden of disease.

The study purposefully erred to be conservative in estimating the environmental contribution to global burden of disease. The scientific literature, the main basis for expert opinion, was poor for many diseases or risks, and experts were therefore not able to consider the full links between environment and disease. This lack of evidence for some environmental risks include contaminants in our air, water, and food, and other risks in our environment, which often have complex linkages with disease that cannot be measured with current risk assessment tools for populations. The results can, however, be used to identify the research gaps for many diseases, risk factors, and integrated approaches.

The study does not address the cost or cost-effectiveness of interventions, which will be addressed in a later report.

Within these limitations, the compilation of the evidence of environmental contributions to all diseases presents us with the following implications.

Environmental Risks Account for a Large Fraction of the Global Disease Burden

The evidence that modifiable environmental factors contribute to 85 of 102 diseases, and account for 24% of the global disease burden, represents an important increase compared with previous systematically collected evidence (eg, 10% as estimated by the Comparative Risk Assessment) and highlights the great potential of environmental action for improving public health. This potential is likely understated because the methods applied in this study are likely to have led to conservative estimates of the environmental disease burden.

Developing Countries Bear Most of the Environmental Disease Burden

Currently, people in developing countries lose many more healthy life years to environmental causes than do people in developed countries. For infectious diseases, the per capita loss of healthy life years from environmental risks is 15 times higher in developing countries and approximately twice as high for unintentional injuries. Overall, there was no difference in the disease burden between developed and developing countries for noncommunicable diseases, although per capita rates for cancers and cardiovascular diseases were approximately twice as high in developed countries.

Children Are at Greatest Risk From Environmental Factors

Children experience a disproportionate share of the environmental disease burden with the per capita rate for DALYs lost in children under 5 years being 5 times that in the total population. Diarrheal diseases, lower respiratory infections, malaria, and malnutrition (including the impact of malnutrition on infectious diseases) all have a large environmental component and disproportionately impact on children.

Equitable and Sustainable Interventions Are Available

Environmental health actions generally produce longer-term impacts that go beyond the health sector. Providing safe water and adequate sanitation, for example, can return 7 times the initial investment.[156] Similarly, a switch to cleaner fuels can produce returns of 3 times the investment over a 10-year period.[157]

TABLE 2. Attributable Fractions and Disease Burden (deaths and DALYs) Resulting From the Environment*

	Deaths (Thousands)		DALYs (Thousands)		Attributable Fraction
	World	Developing Countries	World	Developing Countries	Best Estimate % (95% CI)
Total disease burden†	57,029	43,599	1,490,126	1,276,552	
Total environmental disease burden‡	13,295	10,994	353,572	318,660	
Environmental burden as percentage of total	23%	25%	24%	25%	
Cause-specific disease burden resulting from the environment					
Lower respiratory infections	1516	1403	37,084	35,912	Developed: 20 (15–25) Developing: 42 (32–47)
Upper respiratory infections and otitis	20	18	806	742	Developed: 25 (15–38) Developing: 12 (5–18)
Diarrheal diseases	1682	1664	57,966	57,190	Developed: 90 (75–98) Developing: 94 (84–98)
Malaria	526	526	19,241	19,230	42 (30–53)
Intestinal nematode infections	12	12	2948	2945	100 (—)
Trachoma	0	0	2320	2319	100 (—)
Schistosomiasis	15	15	1698	1697	100 (—)
Chagas disease	8	8	370	366	56 (31–80)
Lymphatic filariasis	0	0	3791	3790	66 (35–86)
Onchocerciasis	0	0	56	56	10 (7–13)
Leishmaniasis	14	14	553	551	26 (12–40)
Dengue	18	18	586	586	95 (90–99)
Japanese encephalitis	13	13	671	671	95 (90–99)
HIV/AIDS (>15 yr)	259	256	7594	7459	9 (5–14)
Sexually transmitted diseases (>15 yr)	35	35	1950	1915	17 (15–19)
Hepatitis B (>15 yr)	3	3	94	92	1 (1–3)
Tuberculosis	285	271	6341	6050	18 (9–35)
Perinatal conditions	270	262	10,666	10,336	Developed: 11 (3–25) Developing: 6 (2–10)
Congenital anomalies	27	24	1473	1321	5 (2–10)
Malnutrition§	74	74	7446	7352	50 (39–61)
Childhood-cluster diseases¶	276	276	10,064	10,043	24 (17–31)
Meningitis¶	13	12	675	643	11 (8–14)
Cancer, total	1385	836	14,504	9517	19 (12–29)
Neuropsychiatric disorders, total	91	62	24,448	20,397	13 (10–16)
Depression	1	1	5334	4097	8 (3–17)
Bipolar affective disorder	0	0	504	420	4 (0–8)
Schizophrenia	1	1	626	534	4 (1–10)
Epilepsy	28	25	1625	1498	Developed: (2–14) Developing: 23 (2–55)
Alcohol use disorder	9	5	1988	1238	10 (2–20)
Alzheimer and other dementias	16	7	417	216	4 (1–9)
Parkinson disease	5	2	77	37	5 (1–9)
Multiple sclerosis	1	0	48	33	3 (0–9)
Drug use disorders	2	2	214	147	3 (0–9)
Posttraumatic stress disorder	0	0	641	500	19 (4–40)
Obsessive-compulsive disorder	0	0	159	123	3 (0–8)
Panic disorder	0	0	378	310	6 (0–17)
Insomnia	0	0	705	497	20 (6–40)
Migraine	0	0	786	591	10 (1–27)
Mental retardation, lead-caused	5	4	9925	9426	100 (—)
Other neuropsychiatric disorders	23	15	1021	729	9 (3–17)
Cataracts	0	0	1806	1765	7 (5–10)
Deafness	0	0	4284	3589	16 (11–21)

(*Continued*)

TABLE 2. (*Continued*)

	Deaths (Thousands)		DALYs (Thousands)		Attributable Fraction
	World	Developing Countries	World	Developing Countries	Best Estimate % (95% CI)
Cardiovascular diseases	2571	1566	23,238	15,906	14 (7–23)
Chronic obstructive pulmonary disease	1312	1234	11,654	10,530	42 (37–47)
Asthma	106	82	6745	5638	44 (26–53)
Musculoskeletal diseases, total	12	7	5161	3729	17 (13–22)
Low back pain	1	0	855	716	37 (26–48)
Osteoarthritis	1	0	2941	2066	20 (13–26)
Rheumatoid arthritis	3	2	740	504	17 (7–29)
Other musculoskeletal diseases	8	5	626	443	15 (7–23)
Road traffic injuries	467	412	15,295	13,720	40 (25–57)
Poisonings	243	158	5235	3521	71 (52–85)
Falls	123	91	5102	4313	31 (16–60)
Fires	22	20	800	746	7 (3–11)
Drownings	277	244	7871	7135	Developed: 54 (30–76) Developing: 74 (48–92)
Other unintentional injuries	402	323	21,465	18,915	45 (22–76)
Suicide	258	207	6189	5135	30 (22–37)
Violence	105	88	4015	3478	19 (7–31)

*Region-specific attributable fractions are presented in the full report.[1] Total population: 6,224,985,000; developing countries: 4,858,118,000. Not all 85 diseases and injuries are shown, because some are grouped into categories, and minor diseases or diseases with small environmental contributions are not listed.

†Includes environmental and nonenvironmental burden.

‡Subtotals for the disease and injury categories do not add up to the total environmental disease burden because minor diseases or diseases secondary to other conditions are not listed.

§Only protein–energy malnutrition, not malnutrition as a consequence of other diseases.

¶Only as a consequence of malnutrition related to environmental risks.

Developed indicates developed countries; developing, developing countries.

Interventions for Healthy Environments Can Have an Important Impact Toward Achieving the Millennium Development Goals

Environmental interventions contribute to goal 1: to eradicate extreme poverty and hunger, because many environmental risks disproportionately affect poorer populations. Environmentally caused disease can also reduce earnings, which in turn reinforces the cycle of poverty and hunger. Environmental action to relieve the burden of disease would thus help to break the poverty. The 60-fold difference in per capita malnutrition rates between the highest and lowest region underline the potential to combat these inequalities with environmental action. Environmental action to reduce the disease burden would contribute to goal 2: to achieve universal primary education, because healthy children have more time to spend on education. Children spending less time collecting solid fuels or drinking water would also have more time for education. Installing adequate latrines at schools would improve the attendance of girls. The contributions of environmental modification to goal 3—to promote gender equality and empower women—

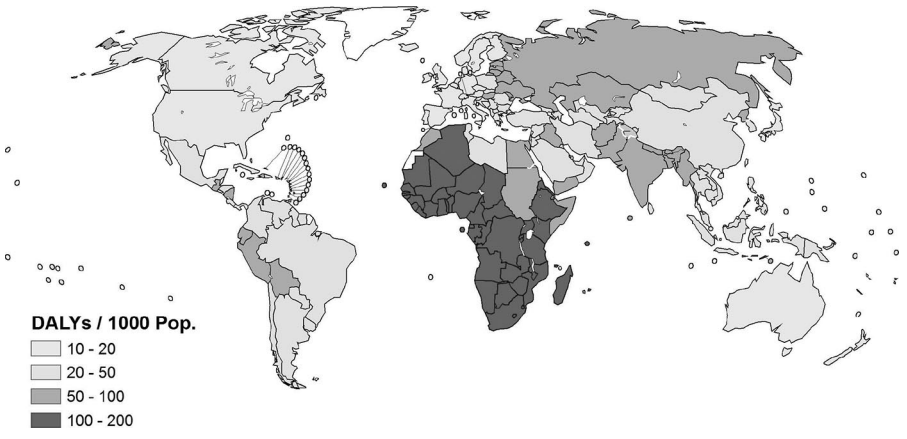

FIGURE 3. Disability-adjusted life-years (DALYs) due to environmental risk factors per 1000 population by World Health Organization subregion[1] for the year 2002. The disease burden is measured in DALYs, a summary measure of death and disability.

are similar to those for goal 2, because women, like children, often spend time collecting drinking water or solid fuels. Environmental action to provide drinking water, for example, would free the women to generate income and improve the nutritional status of the family, because women are generally the main caregivers for household members.

Diarrheal diseases, lower respiratory infections, and malaria all have large environmental components with attributable fractions of 94%, 42%, and 41%, respectively, and all are big child killers. Interventions against these diseases would thus contribute to goal 4: to reduce the child mortality rate.

Environmental interventions to provide safe and sustainable sources of water and clean energy supplies could reduce the number of deaths from diarrhea and lower respiratory infections by 2 million per year. Environmental-related transmission of disease results in half a million deaths annually from malaria and to one fourth of a million deaths from HIV/AIDS. Environmental action thus makes significant and even necessary contributions to achieving goal 6: to combat HIV/AIDS, malaria, and other diseases. Key environmental interventions for goal 6 such as providing clean household fuels, safe water, and sanitation greatly contribute to goal 7: to ensure a sustainable environment. Environmental health action thus has the potential to make a significant contribution toward achieving the Millennium Development Goals and may even be essential for success.

In summary, we believe that this study presents a useful analytic framework for collecting and presenting scientific evidence that is of direct relevance to policymakers and other stakeholders both in measuring the overall impact of environmental risk factors on human health and in highlighting specific areas in which environmental interventions should bring about the greatest human health gains. Applying this approach, and incorporating the best available evidence, suggests that creating healthier environments can prevent approximately one fourth of the disease burden globally in a way that is sustainable, improves equity, and brings multiple benefits. It therefore supports the case that interventions for healthy environments should be an important component of any strategy to improve global public health.

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