How Much Global Ill Health Is Attributable to Environmental Factors?

Kirk R. Smith,1 Carlos F. Corvalán2, and Tord Kjellström3

Over the years, estimates have been made of the portions of human mortality and morbidity that can be attributed to environmental factors. Frustratingly, however, even for a single category of disease such as cancer, these estimates have often varied widely. Here we attempt to explain why such efforts have come to such different results in the past and to provide guidance for doing such estimates more consistently in the future to avoid the most important pitfalls. We do so by carefully defining what we mean by the terms "environmental," "ill health," and "attributable." Finally, based on these recommendations, we attempt our own estimate, appropriately qualified according to the many remaining uncertainties. Our estimate is that 25-33% of the global burden of disease can be attributed to environmental risk factors. Children under 5 years of age seem to bear the largest environmental burden, and the portion of disease due to environmental risks seems to decrease with economic development. A summary of these estimates first appeared in the 1997 report, "Health and Environment in Sustainable Development," which was the World Health Organization's contribution to the 5-year anniversary of the Rio Earth Summit. A full explanation of how these estimates were made is first presented here. We end with a call for a program of "strategic epidemiology," which would be designed to fill important gaps in the understanding of major environmental health risks in important population groups worldwide. (Epidemiology 1999;10:573-584)

Keywords: environmental exposures, morbidity, mortality, children, environmental health risks, populations, global factors, public health.

What is "Environment" in a Health Context?

The strict medical definition of environmental causes of diseases would be all those that are not genetic. This is the classic dichotomy between "nature" and "nurture," in which environmental factors include all those that affect the organism after conception regardless of whether they are mediated by social conditions and individual choice or through environmental media. It could be argued even further, however, that genetic factors are actually also environmental, but merely on a different time scale. Thus, mutation, natural selection, and other mechanisms of evolution have changed the genetic composition of humanity according to environmental conditions existing in the past. In this context, ie, in which current genes are seen as the outcome of previous environments, all diseases are entirely environmental.1

Neither of these definitions ("diseases are entirely environmental" or "all nongenetic causes are environmental") is sufficiently useful for most purposes, and both fly somewhat in the face of common everyday understanding of what constitutes an environmental factor. In terms of health, the most important difference from common perception of the term is the inclusion of "behavioral" or "life-style" factors.2 In particular, diet, including alcohol, and smoking are extremely significant risk factors for a range of important diseases and thus for total health status in many parts of the world. Yet, their inclusion as environmental risk factors would tend to
TABLE 1. Traditional "Natural" Hazards in the Environment*

| Constant search for sufficient food and water while avoiding natural toxins |
| Infections and parasites that spread from person to person or animal to person through |
| air, food, water, or insects |
| Dust, damp, woodsmoke, pollen, and other airborne hazards |
| Injuries from falls, fires, and animal attacks |
| Heat, cold, rain, snow, wind, natural disasters, and other adverse conditions |

* Expanded from Ref. 4.

overwhelm the other, more conventionally understood environmental factors.\(^3\) Furthermore, the most effective interventions for mitigation tend to be somewhat different from those for more conventional environmental factors, such as pollution.

There at least two other major risk categories that introduce ambiguity. Some of the important social risk factors for disease, including crime, stress, and war, being external to the body, are sometimes classified as environmental. In addition, natural hazards, such as earthquakes and inclement weather, although clearly "environmental" in some contexts, are sometimes not considered environmental because their frequency and scale are not generally affected by human actions. Thus, there is sometimes an unstated presumption that environmental health deals only with those aspects of the environment that are affected measurably by human activities and not those due to nature in the raw. Indeed, the term "natural" has come to imply clean and safe to many people. This view could only develop in recent history in rich countries, however, because most of humanity has spent most of history protecting itself from a range of far-from-benign natural environmental conditions, some of which are listed in Table 1.\(^3\)

Figure 1 shows one way to represent the relation among these major categories of risk factors. It may not be worthwhile to attempt to be too precise, because the demarcations between categories are not sharp. For ex, ample, even diet, alcohol, and smoking, while certainly being functions of individual behavior, are also functions of the social environment.

![FIGURE 1. Different definitions of what constitute “environmental factors.”](image-url)

Another way to define the scope of environmental health is in terms of measurable stressors that penetrate from the outer environment across the body barriers to affect bodily health. The usual pathways mentioned are ingestion, inhalation, and dermal/placental absorption/penetration. Clearly the eyes and ears ought to be added to this conventional list however. Ultraviolet light, laser light, and noise, for example, are conventionally measured stressors that can cause ill health without involving the lungs, gastrointestinal tract, or skin. The point of ambiguity is reached, however, when it is not toxic stressors in the usual chemical or physical sense, but rather toxic information content that reaches the sense organs to cause ill health, for example, in the form of verbal child abuse, racism, or television violence.

Some economists take the approach that environmental issues are those in which the effects are externalities, ie, that they occur to a group other than those making the decisions about the activities that cause them. When this happens, it is argued, there is justification for social (government) action to either rearrange the marketplace such that the externalities are internalized (for example, pollution taxes) or to regulate. Thus, urban outdoor air pollution, which is clearly an externality, would be included, but household indoor air pollution caused by sources within the household would not. There are severe problems with this argument in practice, however. For example, it assumes perfect information, ie, that householders understand the risks, whereas individuals are clearly not able to detect even rather large environmental risks on their own (or discriminate between minuscule and significant risks). It also assumes that the household is a rational decisionmaking unit, when it is clear in many societies that there are significant differences in power and risk among household members. Finally, even if making decisions rationally and understanding the risks, the capability of households to enact solutions individually may be sharply limited. (How, for example, can individual households change national oil policy to make cleaner household fuels available?)

Perhaps most importantly, dismissing household u, any other risk factors because in some theoretical sense they are not strict externalities flies in the face of public health tradition. This tradition is to find and reduce all threats to health no matter where they occur. Thus, for example, all benzene molecules, no matter from indoor or outdoor sources, are to be kept away from people’s breathing zones; there is no division into acceptable and unacceptable molecules.

It is often noted that one of the strongest arguments for the existence of significant environmental risk factors is the large difference in rates for the same diseases in different parts of the world. Although these differences can be deeply confounded by diet, smoking, and other quasi-environmental differences, as well as genetic variation in some cases, the difference in rates offers the
best route for helping separate out the true environmental component for many diseases.

As discussed below, environmental risk factors are usually addressed only as to their effect in causing disease. Taking a burden-of-disease approach, however, adds to the discussion the importance of variation in disease prognosis. Clearly, environment plays an important role here as well, and probably for nearly every kind of disease. Even diseases the generation of which has little to do with current environmental conditions, for example, genetic and sexually transmitted diseases (STDs), will take different courses depending on the environmental conditions to which their victims are subjected. Thus, like nutrition, the total burden, if not the incidence, of nearly every disease and injury is affected to some degree by environmental factors.

The two most fundamental parameters affecting the degree to which a risk factor is defined to be environmental are the nonindependent choices of time period and environmental baseline. As discussed above, if a sufficiently long time horizon is taken, all disease is environmental, even that related to genetic factors. If causation is confined to an extremely limited period, however, long-term environmental health threats such as climate change would be excluded. Some intermediate choice seems most appropriate, perhaps, as in the “rule against perpetuities” in English Common Law, roughly the potential length of one lifetime, ie, 100 years, without excluding potential environmental risks we may be creating for future generations. Long-term environmental risks, however, are not included in these analyses.

Choice of the baseline is equally critical, because determination of the existence and scale of environmental risk requires answering, directly or implicitly, the question “Compared with what?” Because humans have never lived with zero environmental risk, nor is there such a time in prospect, the choice of a baseline is often not easy. For some categories of risk, for example, environmental circulation of synthetic chemicals, a baseline of 0 may be suitable. For others, however, it may not be, for example, airborne particulates, ionizing radiation, ultraviolet light, and inclement weather.

In summary, as will be explained separately for each major disease category in a later section (Estimated Environmental Portion of the Global Burden of Disease), we have generally taken the following approaches in dealing with the question of what will be included as environmental risk factors in our burden of disease determinations:

- We do not include genetic risk factors, as we consider only current and future environments, not past ones.
- We do not include the major risk factors of diet and active smoking, but do include nonnutritional elements of diet, including food additives, infectious agents, pesticides, etc, and passive smoking (environmental tobacco smoke).
- We do, however, include behavioral factors related to personal and household hygiene, just as we do for behavioral factors leading to community and larger-scale pollution.
- We include a modest component of environmental risk in the direct and indirect risks of malnutrition to account for degraded soils, floods, and other human-engendered impacts on the quantity, quality, and distribution of food.
- We assign a component of injuries to environmental factors on the basis of the substantial variations in rates among different parts of the world and, also, the recognition that even social nonphysical/chemical stressors are to some extent environmental. The baseline is not taken as zero risk, however.
- We include a small component of environmental risk for every disease category because of the influence of the environment on disease outcome.
- We include health impacts of the natural environment, such as dust exposure and natural disasters, although we do not try to determine the component caused by human activities, such as desertification and global warming.

What Is Meant by "Disease?"

Although we endorse the ideals behind the World Health Organization’s definition of health as not just the absence of disease, as proposed in its constitution in 1948, here we focus only on the disease portion, ie, the environmental component of the total burden of disease, not of the total burden of ill health. We also do not attempt to address the conceptual and measurement difficulties inherent even in defining disease. Rather, we use the Global Burden of Disease (GBD) with relatively minor adjustments. The creation of this database, however, required the assistance of a large number of experts to address a range of such conceptual and measurement issues. Among the most difficult of these issues were establishing a unit of measurement by which death, disease, and injury can be combined; choosing appropriate groupings by age and sex; defining appropriate geographic boundaries; combining effects in different time periods; deciding whether effects at different ages should be weighted differently; reconciling cause of death and disease when different diseases are involved [for example, AIDS victims who contract tuberculosis (TB)]; and establishing categories and weights for the wide range of disabilities associated with different diseases.

To make the dataset more tractable for this article, we have confined it to those disease groupings that each cause at least 1% of the GBD (see Table 2). The disability-adjusted life year (DALY) is used as the basic unit of ill health. The total in DALYs is determined by summing the years of lost life due to premature deaths plus the weighted years of disability due to a particular disease or risk factor. Shown also are the separate DALY sums and populations for more-developed and less-developed countries, showing the much larger burden of disease per capita in the latter. (The difference is even larger if age distributions are taken into account.)
TABLE 2. Global Burden of Death and Diseases in 1990 Showing Those 22 Categories Causing at Least 1% of Lost Disability-Adjusted Life Years (DALYs)

<table>
<thead>
<tr>
<th>Category</th>
<th>World</th>
<th>LECr*</th>
<th>MDCr*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute respiratory infections (ARI)</td>
<td>8.5</td>
<td>9.4</td>
<td>1.6%</td>
</tr>
<tr>
<td>Diarrheal</td>
<td>7.2</td>
<td>8.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Perinatal conditions</td>
<td>6.7</td>
<td>7.3</td>
<td>1.9</td>
</tr>
<tr>
<td>Child cluster (measles, pertussis, polio, tetanus, diphtheria)</td>
<td>5.2</td>
<td>5.8</td>
<td>0.008</td>
</tr>
<tr>
<td>Cancer</td>
<td>5.1</td>
<td>4.0</td>
<td>13.7</td>
</tr>
<tr>
<td>Depression</td>
<td>4.7</td>
<td>4.3</td>
<td>7.7</td>
</tr>
<tr>
<td>Malnutrition (direct effects)</td>
<td>3.7</td>
<td>4.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Heart (ischemic)</td>
<td>3.4</td>
<td>2.5</td>
<td>9.9</td>
</tr>
<tr>
<td>Stroke (cerebrovascular disease)</td>
<td>2.8</td>
<td>2.4</td>
<td>5.9</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>2.8</td>
<td>3.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Road accident</td>
<td>2.5</td>
<td>2.2</td>
<td>4.4</td>
</tr>
<tr>
<td>Congenital anomalies</td>
<td>2.4</td>
<td>2.4</td>
<td>2.2</td>
</tr>
<tr>
<td>Malarial</td>
<td>2.3</td>
<td>2.6</td>
<td>0.003</td>
</tr>
<tr>
<td>Maternal conditions</td>
<td>2.2</td>
<td>2.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Sexually transmitted diseases/human immunodeficiency virus</td>
<td>2.2</td>
<td>2.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease (COPD)</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Falls</td>
<td>1.9</td>
<td>2.0</td>
<td>1.5</td>
</tr>
<tr>
<td>War</td>
<td>1.5</td>
<td>1.5</td>
<td>0.7</td>
</tr>
<tr>
<td>Suicide</td>
<td>1.4</td>
<td>1.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Alcohol (direct effects)</td>
<td>1.2</td>
<td>0.8</td>
<td>4.0</td>
</tr>
<tr>
<td>Drowning</td>
<td>1.1</td>
<td>1.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Percentage of total in these 22 categories</td>
<td>72%</td>
<td>73%</td>
<td>64%</td>
</tr>
<tr>
<td>Total global lost DALYs (million)</td>
<td>1379</td>
<td>1218</td>
<td>161</td>
</tr>
<tr>
<td>Population (million)</td>
<td>5260</td>
<td>4120</td>
<td>1140</td>
</tr>
<tr>
<td>Total DALYs per 1000 capita (not age-adjusted)</td>
<td>260</td>
<td>300</td>
<td>140</td>
</tr>
</tbody>
</table>

* LDCs less developed countries.


The only choices made in the GBD that we have altered slightly from the published GBD database relate to the grouping of diseases. There is no unique or absolute way of doing such grouping. Diseases in the GBD, for example, have been grouped, inter alia, according to biological criteria (eg, helminths), presumed common mechanism (eg, malignant neoplasms), organ system (eg, cardiovascular), age (eg, perinatal), sex (eg, maternal conditions), type of intervention (eg, child cluster), location (eg, tropical cluster), cause (eg, road accidents), and motive (eg, intentional vs unintentional accidents). The way diseases are grouped, although often reflecting historical development of understanding and convenience, can have significant implications for policy.

This is illustrated by the most important grouping in Table 2, acute respiratory infections (ARI). Up until the 1970s, the many separate bacterial and viral diseases that now make up ARI were often listed in separate groupings, often inconsistently from one tabulation to the next. Realization came about, however, that although different microbiologically, the group had common risk factors, common gross symptoms, and common outcomes, particularly sharing a high risk of producing life-threatening pneumonia in children in developing countries.9 Grouping them together gave them much greater visibility in health policy, particularly because together they exceed diarrheal diseases (another, but older, grouping) to become the single largest category.

The child cluster grouping (measles, tetanus, pertussis, polio, and diphtheria) is another example, in which the importance of child vaccination programs became strikingly emphasized by placing the five diseases together for which relatively inexpensive and reliable vaccines are available. In this case, of course, the diseases do not even have the same risk factors, symptoms, or outcomes. In both of these groupings, the biological or medical classifications would be much less useful for policy than focusing on common interventions.

We have made slight adjustments to the GBD in three major groupings, as follows.

- Depression here includes only unipolar and bipolar depression. Other conditions listed under "neuropsychiatric conditions" in the GBD were not included. Inclusion of all categories would bring the total to 10.5% of the G13D.
- Heart disease here only includes ischemic heart disease and is separated from the next category, cerebrovascular disease, because these conditions have quite different outcomes and are often investigated separately in environmental epidemiological studies. In the GBD, these two categories are combined, along with the much smaller subcategories of rheumatic and inflammatory heart disease, into the category of "cardiovascular" disease (these latter two infection-related subcategories together add 1.2% additional to the GBD).
- We have combined the separate GBD categories of "other STDs" and "human immunodeficiency virus (H1W) into one grouping called STD/HIV.

Further modifications of groupings might also be considered. For example, it might be suitable to create a new grouping, "food/water cluster," by adding diarrhea to some fraction of intestinal nematode infections and the tropical-cluster diseases (filariasis, leishmaniasis, schisto-
somiasis, trypanosomiasis, etc), which account, respectively, for an additional 0.4% and 0.8% of the GBD. This would raise the visibility of food/water quality and hygiene as a potential intervention.

Inclusion of asthma would add another 0.8% to the GBD for chronic obstructive pulmonary disease (COPD) in a category that could be called "chronic respiratory cluster." Given some indication of common risk factors, this might be appropriate. On the other hand, the still-uncertain and mysterious apparent rise in asthma rates in some parts of the world probably argues for keeping it separate so that increases can be more easily highlighted.

What is Meant by "Attributable?"

By "attributable environmental risk," we mean the percentage of a particular disease category that would be eliminated if environmental risk factors were reduced to their lowest feasible values. As it considers both the prevalence of the exposures and strength of the risks, this term corresponds to "attributable risk percent (population)" in the Dictionary of Epidemiology.

Most important diseases with significant environmental components actually have multiple risk factors, a characteristic that on the one hand makes understanding more difficult, but on the other, offers multiple routes for finding useful interventions. Take again, for example, the largest disease category in the world, ARI. As shown in Figure 2, in common with many diseases in the developing world, malnutrition plays a critically important role. To save * lives, case management (pinpointing and then treating ARI-afflicted children with antibiotics) can also be effective. Some percentage of ARI is thought to be preventable with vaccinations, as well. Finally, another important risk factor is other diseases, such as diarrhea, AIDS, and measles. Children with these other diseases are more likely to contract ARI, which classifies these diseases as ARI risk factors.

When quantified, this multiple risk framework can be a powerful guide to designing cost-effective and timely interventions to reduce disease burdens. It also provides a means to start examining possible synergisms among interventions.

COMPETING RISKS

Given lack of complete knowledge, it is easily seen how the fractions due to known risk factors might add to less than 100%. But surely, most people might say, they could never add to more than 100%, as they do in Figure 2. (After all, how can we prevent more disease than there actually is?)

In reality, however, most of the important risk factors act not to create a certain number of disease cases, but to enhance the existing number of cases. In this way, they can add to more than 100%. Take a relatively straightforward hypothetical situation of 1,000 annual deaths from auto accidents along a stretch of dangerous highway. Studies might have shown that these could be reduced by 20% through requiring headlights to be used during the day, 40% through stricter speed limits, 50% by putting in more stop lights, 90% by installing speed bumps, 98% by having a police officer accompany each car, and so on. Here it is easily seen that the total, 298%, is open ended and reflects the detail with which we understand the problem and our ingenuity in finding ways to deal with it.

The reason that risk factors often add to more than 100% is that they are usually not completely independent; changes in one will affect the others. In our highway safety problem, for example, consider that we are choosing whether to save 100 lives by daytime headlights or 200 through speed limits. Can we save 300 by doing both? No, because once one is implemented the overall situation changes and the remaining potential benefits of the other risk factors will be reduced. In this case, many of the 200 people whose lives might be saved in a speed-limit campaign might also have been saved by daytime headlights. Depending on the degree of non-independence, the remaining benefit of headlights might only be 50, for example, making the total equal 250, not 300.

The same is so with ARI. Reduction of ARI deaths by 25% through vaccination, for example, would reduce the number of lives left to be saved through interventions affecting the other risk factors. Better nutrition, for an illustration, might still be able to save 30%, but it would now be 30% of a lower total. A somewhat counterintuitive corollary is that the number of deaths accountable to each risk factor depends on the order of listing the risk factors. The closer to the top of the list, the higher the savings for each factor.

The only practical way to determine the contribution of a risk factor (attributable risk in health terminology), therefore, is in terms of the degree to which the disease would be changed by reducing or increasing a particular
risk factor that we can conceptualize and manipulate in relation to other existing risk factors. There may be hundreds of potential interventions, but we usually do not bother describing those that have no practical meaning, for example, that if we could only teach people to breathe less, they might not be so affected by air pollution (or assign a police officer to every car to reduce traffic accidents).

It is well to remember, therefore, that the total attributable risk for all the important risk factors viewed independently often adds to more than 100%. Each risk factor must be considered in light of the others. Except in relatively rare cases, as when a specific chemical is associated with a particular type of unusual cancer, the risk factors will interact rather than simply add. Progress in reducing one risk factor will affect the remaining potential of the others. Indeed, the more potentially useful interventions are known, the greater the attributable risk. In contrast, it is the diseases for which known attributable risks add to less than 100% that are most troublesome. Breast cancer would seem to fit this description at present.

Furthermore, the statement that large fractions of ARI are attributable to air pollution, poor housing, crowding, and chilling, is not incompatible with the also-incontrovertible truth that large fractions are also due to lack of breastfeeding, vitamin A deficiency, and malnutrition in general. In addition, the more differentiated the major categories such as malnutrition and environment become, the apparently larger the total aggregated attributable risk for the general category becomes. When all of the subcategories are combined together into each of the main categories of either nutrition or environment, however, they cannot be simply added because they interact. Thus, all possible improvements by nutrition alone will have a limit less than if breastfeeding, vitamin A, protein supplements, etc, taken separately are added together.

The most basic of risk factors, of course, is poverty. But what is poverty? Just lack of money at the household level is an insufficient criterion, because provision of money on its own is not effective in most cases in producing permanent and substantial improvements. If one assumes, however, that alleviation of poverty would bring along with it the advantages of better education, nutrition, environment, access to medical care, and so on that has generally accompanied it in the currently developed countries, the attribution of disease in the third world to poverty is almost a tautology.

More tellingly, much of the history of public health can be viewed as success in pinpointing the specific subcategories of attributable risk in the form of better nutrition, environment, and medical care that can be effectively modified by education, technology, and management to achieve better health before people become rich. To propose poverty alleviation as the primary means to improve health is to ignore the huge potential improvements that can be achieved well before that far-off day when poverty is eliminated. It also fails to recognize that improved health is itself a prerequisite for achieving and maintaining viable sustainable economic development. The causality goes both ways.

What is "Attributable?"
The following are some basic principles related to determining the fraction of a disease category that is attributable to environmental risk factors.

- All known attributable risks for a disease often add to more than 100% and, consequently, a large attributable fraction claimed for one risk factor does not necessarily imply that another risk factor cannot also have a large attributable fraction.
- Size of individual attributable risks depends on order that different risk factors are examined, because if one risk factor is reduced, the remaining disease available to be reduced by other risk factors will decrease.
- Existence and size of an attributable risk factor presumes existence of feasible intervention, because there is an unlimited number of hypothetical risk factors that cannot be manipulated with current knowledge or feasible application of resources.
- Defining baselines can be important; ie, it is often necessary to specify a minimum possible or reasonably attainable risk, particularly for environmental risk factors that cannot be feasibly reduced to zero levels because, for example, of natural background.

Estimated Environmental Portion of the Global Burden of Disease
On the basis of the discussions above, we lay out here our principal assumptions made in (1) determining what is meant by environment for each category, (2) accounting various diseases into one category, and (3) ascribing attributable risk.

General Principles
Viable Intervention
Even though measles, polio, tetanus, and other important infectious diseases have significant environmental components (and indeed were reduced considerably in the currently developed countries by environment/nutrition improvements before vaccinations were developed), we do not account a high proportion of their risk to environment, because effective vaccines are now available. For other such environmentally mediated infectious diseases that do not currently have effective vaccines, however, we account a high proportion to environment (for example, ARI and malaria). TB is Environment First
We assume that environmental actions are taken first; for example, if a disease is seen to have a significant environmental as well as other components, we consider what fraction might be averted first through feasible environmental interventions, before other interventions are applied. For example, although we recognize that ARI burden can be substantially reduced through better
nutrition, we assume the undertaking of environmental improvement before other interventions are undertaken.

**Prevention**

We are emphasizing prevention rather than curative measures. Thus, although diarrhea deaths are averted effectively through oral rehydration therapy in the immediate term, the long-term solution is to minimize actual incidence through environmental sanitation, food safety, and related efforts.

**Cost Effectiveness**

We have not done cost-effectiveness calculations to determine whether environmental interventions are more attractive than other kinds of intervention in every case. Nevertheless, we believe the levels of risk we attribute to environmental factors are compatible with the extent of interventions that are at least within range of technical and economic feasibility, particularly considering the nonhealth benefits that often accompany them.

**Disease Prognosis**

Although STDs and other disease categories have little component of environmental risk in terms of incidence, improved environmental conditions would ameliorate to some extent the course of these diseases; for example, the same number of people might contract STDs, but the resulting disease would be milder and death would be delayed longer, with better living and working conditions.

**Nutrition**

Considering that malnutrition also serves as an indirect risk factor for both vulnerability and recovery from essentially all diseases and injuries and that environment plays a role in malnutrition, a small additional environmental component is included for every disease category.

**Minimum**

The combination of disease prognosis and nutrition, above, is taken as 5%; ie, the minimum environmental component of any disease category is 5%.

**Maximum**

Even though diarrhea and other disease categories might be arguably 100% environmental, we do not assign them full weight because of the importance of medical care and nutrition in determining the course of disease. For example, although the incidence of diarrhea might be greatly reduced if Bangladesh were to have the water, sanitation, and hygiene situation of Sweden, without the medical care and nutrition available in Sweden, there would still be significantly more ill health produced by the remaining incidence than would be found in Sweden. No disease category is assigned more than 90% to environmental risks.

**Exclusions**

We have defined sexual behavior, active smoking, alcohol and drug abuse, and most criminal violence to be principally nonenvironmental risk factors.

**Accidents**

Road accidents, falls, and drowning are considered to have large environmental/occupational components, principally because of the large differences in rates that exist in different parts of the world.

**Housing**

We include what might be called the "housing complex," ie, crowding/chilling/ventilation/drainage, as environmental factors.

**Workplace**

All occupational injuries and illnesses are counted as environmental, including those of military personnel.

**Issues Specific To Each Disease Category**

Here we examine one by one all of the disease categories responsible for at least 1% of the global burden (Table 2). The rough global percentage of each category we attribute to environment is shown as a range in parentheses at the end of each disease discussion. We believe these estimates to be reasonable, but here they are not backed by the kind of extensive review of the exposure assessment and epidemiological literature that would be needed to be more certain.

ARDS here are taken to include upper and lower respiratory infections as well as otitis media. They mostly (80%) affect children under 5 years of age. ARI, particularly as pneumonia in young children, is known to have been essentially eliminated by environmental and nutritional improvements in developed countries, largely before the advent of relevant antibiotics and vaccines. Chief environmental risk factors are ambient air pollution and housing conditions, such as chilling, crowding, and indoor air pollution. (40-60%)

Diarrheal diseases mostly (86%) affect young children and are related in the long run nearly entirely to the environmental factors of poor sanitation, hygiene, and access to clean water/food. (80-90%)

Perinatal effects, which include low birth weight, neonatal death, and still birth, have some environmental linkage through exposures to pollution and poor housing experienced by the mother during pregnancy and the infant just after birth. A significant proportion of disease and death in this category is known to be due to diarrhea and ARIs, both of which are primarily environmental. (10-20%)

Child cluster refers to the vaccine-preventable diseases, measles, tetanus, pertussis, polio, and diphtheria, which in principle are largely environmental. Environmental improvements will decrease rates and improve outcomes but are not as effective as vaccines, and thus environment is unlikely to be a competitive initial intervention. (5-10%)

Malignant neoplasms (cancer) encompass quite a varied set of sites and causes. Lung cancer, the largest subcategory, accounts for about one-eighth of the total. For cancer, nutrition, active smoking, and alcohol are not counted as environmental, but occupational causes; food preservatives (including salt) and chemical (includ-
ing passive smoking) and radioactive (including radon) agents are included along with half of infectious agents, which alone account for about 15% of all cancers (20-25%).

Depression does not cause much direct mortality but significant disability and would seem to have only small direct environmental linkages through stress from deteriorating living and working environments. (5-10%)

Malnutrition here only includes direct nutritional deficiencies: iron-deficiency anemia and protein-energy, iodine, and vitamin A deficiencies, and not the increased risk of other diseases. Malnutrition has a modest environmental portion through natural geographic variations, land degradation, and other environmental problems leading to lower food availability and quality. (8-10%)

Ischemic heart disease has a small but verified environmental linkage through air pollution, occupation, and, perhaps also water quality. (8-10%)

Cerebrovascular disease has a suspected linkage through air pollution and occupation. (8-10%)

TB has important household environmental risk factors, including crowding, chilling, and, probably, air pollution. (20-25%)

Road accidents are considered to have a significant environmental/occupational component, plus a component due to environmental (land use and transport) planning. (25-30%)

Congenital effects (birth defects) may have a small environmental/occupational component through chemical exposures during pregnancy. (5-10%)

Malaria cases are nearly all attributable to environmental factors, such as land management and housing. (70-90%)

Maternal causes of death would seem to have a few direct environmental links, through poor household and working conditions. (0-10%)

STDs, including AIDS (HIV), would not seem to have any direct environmental linkages, although the first switch of HIV from animals to humans may have occurred due to environmental disruption. (5%)

Chronic obstructive pulmonary disease is a known outcome of air pollution exposures, both environmental and occupational, and is enhanced by early affliction with ARI. Although most chronic obstructive pulmonary disease in developed countries is due to smoking, this accounts for less than 10% of the world total. (33-50%)

FIGURE 3. Environmental contribution to the global burden of disease—all disease categories, each responsible for at least 1% of lost disability-adjusted life years (DALYs). These 22 conditions account for 72% of the global burden of disease; 25-33% seems to be due to environmental factors.
Falls are considered to have a significant occupational/environmental component. (25-30%)

War injuries/deaths are considered occupational for military personnel and to have a small environmental component for civilians due to conflicts caused by people fleeing to avoid degraded environments. (50-70%)

Suicide has a small component due to stress induced by degraded living and working environments. (5%)

Violence has a significant occupational component plus small environmental contribution to criminal violence in a manner similar to suicide. (15-20%)

Alcohol use here considers only direct health impact, except cirrhosis, and not its contribution to other diseases, other vehicle accidents, fires, etc. The total impact is reduced somewhat, because moderate alcohol use is counted as beneficial to health by lowering the risk of ischemic heart disease. There would seem to be only a small environmental component involving the synergism of poor environmental (housing) conditions with health outcomes. (0-10%)

Drowning is considered to have significant occupational/environmental factors. (25-30%)

These 22 categories account for about 72% of the global burden. No other disease groupings come to more than 1% of the global burden, although several come close, including lower respiratory infections (LRI), cataracts, diabetes, asthma, and trachoma.

Shown in Figure 3 is the summary of these major categories of disease and their estimated attributable environmental portions.

Applying the environmental percentages shown in Figure 3 for each major disease category produces an overall environmental rate of 25-33% for this 72% of the GBD. Although not addressed individually here, the remaining 28% of the GBD consists of many disease categories that also have significant environmental components (for example, asthma, cataracts, trachoma, meningitis, hepatitis, dengue, rheumatic and inflammatory heart disease, encephalitis, digestive disease, dental caries, poisonings, miscellaneous unintentional injuries, tropical Cluster, and other parasitic diseases), as well as some that would seem to have relatively few environmental determinants (for example, genitourinary and musculoskeletal diseases).

Thus, it seems reasonable and probably conservative to expect a similar overall environmental portion, i.e., about one-quarter to one-third.

Recognizing the uncertainty due to insufficient knowledge of etiology and lack of adequate data in many parts of the world, as well as in the conceptual issues discussed above in the definitions of environment, disease, and attribution, we state our final estimate of the environmental portion of the GBD as a range: One-fourth to one-third (25-33%). This represents a somewhat smaller fraction (23-31%) of total world deaths, because much of the burden falls on young children. A wider definition of what constitutes "environmental" and a more flexible definition of attributable risk could easily raise this to 40%.

Assuming that the percentage due to environment in each disease is the same throughout the world, the rough distribution of the attributable environmental portion by major world region is shown in Figure 4. In reality, of course, given the relative age distributions and the major impact of environmental factors on disease affecting young children, a larger fraction is likely to be due to environmental factors in developing countries. Thus, the true distribution is likely even more skewed toward poor regions than shown in the figure.

HEALTH AND ENVIRONMENT IN SUSTAINABLE DEVELOPMENT REPORT

The Health and Environment in Sustainable Development Report shows estimates for only 10 disease categories.
ries. Here, however, we address 22 categories, by adding to and separating some of the original categories (indicated (t) in Table 2), so that all categories responsible for at least 1% each of the total global burden are covered. The environmental fractions for the original 10 have been retained as the high end, except that for TB, which we have here increased from 10% to 25%.

**Environmental Risks for Children**

Globally, about 43% of the total burden of disease due to environmental risks falls on children under 5 years of age, even though they make up only 12% of the population. The absolute burden due to environmental factors for young children varies dramatically by region, however. Figure 5 shows annual DALYs lost per 1,000 persons for the entire population and for those under 5 years of age just for the high end of the 22 categories of ill health in Figure 3. Young children from developed countries (Established Market Economies) by this measure lose only 16 DALYs per 1,000 as compared with 751 per 1,000 in Sub-Saharan Africa, a factor of nearly 50.

The main reason for these large differences is the enormous impacts still imposed in poor countries by the two largest disease categories, ARI and diarrheal diseases. As can be appreciated from Figure 6, the difference in absolute risks for these diseases between developed countries and Sub-Saharan Africa is more than 100-fold. Thus, poor air, food, and water quality at the household level remain the biggest source of environmental risk in much of the world today.

**Conclusions**

Here we list the conclusions in relation to major issues and major needs that can be drawn from the analyses above.

**ISSUES**

1. Environmental quality is an important direct and indirect determinant of human health.
2. People in the poorest countries tend to be most at risk from household-related environmental quality problems, which impose the largest environmental disease burden on humanity.
3. People in middle-income countries tend to be most at risk from community-related environmental quality problems.
4. Although not addressed here, it is probably activities in rich countries that most threaten the global environment.
5. In the world today, it is the health of children under 5 years of age that is most damaged by poor environmental quality.

6. One-quarter to one-third of all ill health in the world today seems to be attributable to environmental factors.

7. Environmental quality is a major factor both in the infectious diseases that tend to affect the poorest population groups and, to a lesser extent, in the chronic diseases that tend to affect richer groups.

**NEEDS**

1. There is an urgent need for more and better coordinated local and global data collection on environmental exposures related to the major environmental health impacts.

2. A global, strategic epidemiological effort is needed to fill gaps in our understanding of the relation between major environmental exposures and ill health in major population groups.

3. There is a need to consider health issues across sectors, because activities in a number of sectors have environmental impacts that lead to health impacts, and there are number of cross-sector interactions.

4. To be most effective, there is a need to consider the entire environmental pathway from driving forces to health impact when designing interventions to improve environmental and health.

5. Needed immediately are accelerated and integrated efforts to improve household environmental conditions in poor countries much more rapidly and more broadly across groups than now seems to be occurring.

6. Needed at all level of development, but particularly in middle-income countries, are more comprehensive and timely introduction of community environmental control efforts.

We have confined our analysis here to current conventional environmental health risks. Not discussed are those emerging risks that probably do not yet account for a large disease burden but have the disturbing potential to do so in the not-too-distant future. Among these, for example, are changes in the "epidemiological environment" of the infectious organisms themselves due to human activities, such as heavy use of antibiotics and the potential health impacts of human-induced climate change.

Perhaps the most striking feature of the results presented here is the importance of environmentally mediated infectious diseases in the global burden of disease. This includes not only those in which infectious agents are carried via environmental pathways, but also, in the form particularly of ARI, those in which environmental risk factors apparently enhance the severity and frequency of infection. This implies that many of the most critical health problems in the world today cannot be solved without major improvement in environmental quality. Such improvements will be needed to achieve true sustainable development on a global basis.
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References