Environmental pollution: An enormous and invisible burden on health systems in low- and middle-income countries

ABSTRACT: Background. Environmental pollution has become the leading risk factor for death in low- and middle-income countries (LMICs). The World Health Organization and others calculate that exposures to polluted air – indoor and outdoor, water and soil resulted in 8.4 million deaths in LMICs in 2012. By comparison, HIV/AIDS causes 1.5 million deaths per year, and malaria and tuberculosis less than 1 million each. The diseases caused by pollution include the traditional scourges of pneumonia and diarrhea, but increasingly they also include chronic, non-communicable diseases (NCDs) such as such as heart disease, stroke and cancer.

Method. We review the diseases caused by pollution and the multiple economic and human burdens that these diseases impose on health systems in countries with already limited resources.

Results. We find that diseases caused by pollution increase health care costs, especially for high-cost NCDs. They impose an unnecessary load on health care delivery systems by increasing hospital staffing needs and thus diverting resources from essential prevention programmes such as childhood immunizations, infection control and maternal and child health. They undermine the development of poor countries by reducing the health, intelligence and economic productivity of entire generations. Pollution is highly preventable and pollution prevention is highly cost-effective. Yet despite their high economic and human costs and amenability to prevention, the diseases caused by pollution have not received the attention that they deserve in policy planning or in the international development agenda.

Conclusion. Pollution is not inevitable. It is a problem that can be solved in our lifetime. Given the great impact of pollution on health and health care resources and the high cost-benefit ratio of pollution prevention, efforts to mitigate pollution should become a key strategic priority for international funders and for governments of LMICs.

Recommendation. Assisting LMICs to prioritize disease prevention through the management of pollution is a highly cost-effective strategy for enhancing population health, reducing the burden on limited health resources and advancing national development.
Institute for Health Metrics and Evaluation (IHME) (6).

**Air pollution**
Contamination of both outdoor air (urban air) and indoor air (cooking stoves) – poses the largest and best characterized pollution-related threat to health. Mortality data for air pollution have recently been revised upward by WHO as new links between air pollution and health have been discovered, most notably links between air pollution, cardiovascular disease and cancer (1, 2).

**Water pollution**
Sewage-contaminated water has long been recognized as a major cause of diarrheal disease (7).

**Soil pollution**
The health impacts of soil pollution have only begun to be studied in detail. Thus mercury, a significant global contaminant of soil and a well-established cause of neurodevelopmental disorders, does not appear in any published databases calculating the Global Burden of Disease because a quantitative relationship between metallic mercury and health has not yet been defined. Data on the number of mercury-contaminated sites worldwide and on the size of the exposed populations are also still incomplete. Preliminary estimates suggest that contaminated soils may be responsible for 13.8% of cancer deaths worldwide (8, 9).

**Globalization – A powerful driver of pollution**
A powerful driver of pollution in LMICs is globalization of the chemical manufacturing industry, the recycling industry and other polluting industries. These industries are relocating from Europe, Japan and the United States to poor countries that lack environmental regulations and technology and thus are the countries in the world least well equipped to deal with environmental contamination. The result is that workers and communities in these countries can be massively exposed to toxic chemicals, often under highly uncontrolled conditions. The Bhopal disaster in India where thousands of people died and were severely injured 30 years ago after acute exposure to methyl isocyanate following an explosion in a pesticide manufacturing facility provides a classic example of the consequences of poorly controlled globalization of the chemical manufacturing industry.
Another slower moving catastrophe may be seen in the case of asbestos (11). Global sales of new asbestos currently amount to 2 million tons per year. Virtually all of this asbestos is used in LMICs. An estimated 1.25 million persons are exposed. A global epidemic of malignant mesothelioma and of the other cancers caused by asbestos may be expected to result. Electronic waste (e-waste) is pouring into poor countries at a rate of almost 40 million tons per year (12). Although not well publicized, the “chemical revolution” is one of the most important of the environmental changes that have transformed the developing world in the past half century.

The need to track global pollution
Mapping of pollution is essential to establishing its health and environmental impacts and to developing remediation strategies (13, 14). Yet at present time only a handful of LMICs have established rudimentary databases for tracking releases of pollutants to the environment. The Global Alliance on Health and Pollution, a consortium of development banks, affected countries, and UN agencies has undertaken preliminary studies in 50 countries, and has the best dataset on contaminated hazardous waste sites worldwide (15).

The diseases caused by pollution
The diseases caused by pollution are diverse. They include pneumonia and diarrheal disease, the two acute diseases traditionally linked to air and water pollution. WHO estimates that 50% of pneumonia deaths worldwide in children younger than five years are attributable to indoor air pollution (1). Deaths from sewage – contaminated water are estimated to account for 56% of deaths from diarrheal diseases.

But additionally it is now recognized that environmental pollution is strongly linked to chronic, non-communicable diseases (NCDs), including the major fatal diseases of adult life – stroke, heart disease and cancer (1, 2). On the basis of new scientific knowledge about the links between pollution and chronic disease, WHO reported in 2014 that indoor and outdoor air pollution are now considered to be responsible for 7 million deaths each year (1). These numbers represent a significant upgrade over previous estimates, and this increase is driven principally by new knowledge of links between air pollution and NCDs gained through large epidemiologic studies in multiple countries. The largest increases in numbers of deaths attributed to air pollution are seen for heart disease (16), stroke (16) and cancer (17).

Figure 3 presents data showing the incremental burden of disease and death attributable to environmental pollution. The number of deaths caused by pollution is greater than that from any other major cause, including HIV/AIDS, malaria or tuberculosis.

Vulnerable populations
Pollution is strongly linked to poverty (18). The overwhelming majority (94%) of the burden of disease and death caused by pollution falls on LMICs. These countries lack strong health and environmental protection programmes. In contrast to High-Income Countries, they are poorly equipped to deal with the problems of pollution. The result is that poor people in developing countries continue to be poisoned, suffer lifelong disabilities, and die prematurely from pollution.

Children are especially vulnerable to environmental pollution (19, 20). Prenatal exposures to pollution can cause birth defects, developmental and neurological disabilities, damage to the immune system, and reproductive impairment (21). Moreover, exposures to pollution during windows of susceptibility in early life have been shown to increase risk for chronic non-communicable diseases in adult life such as hypertension, heart disease, stroke, diabetes, kidney disease and cancer (22–24).

Workers are another group highly vulnerable to pollution, and pollution causes a number of occupational diseases – lead poisoning, acute and chronic pesticide poisoning, silicosis, and the diseases of asbestos (25).

The costs of pollution
Cost is an inevitable, but often overlooked and undercounted consequence of environmental pollution (26). The costs of pollution may be examined under several headings:

+ **Direct medical expenses.** The diseases caused by pollution, especially the high-cost chronic, non-communicable diseases (NCDs) such as stroke, heart disease and cancer that are now linked to air and soil pollution impose heavy financial burdens
on already overburdened health systems in LMICs.

**Indirect health-related costs.** The diseases caused by pollution, especially NCDs are responsible for large indirect health-related costs such as time lost from school and work, costs of rehabilitation and costs of special education.

Estimates have been made of the direct and indirect medical costs of disease caused by environmental pollution. In 2011 Trasande and Liu (27) examined the costs of disease caused by environmental pollution in children in the United States. They found that the annual costs of lead poisoning, prenatal mercury exposure, childhood cancer, asthma, intellectual disability, autism, and attention deficit hyperactivity disorder of environmental origin amount to US$ 76.6 billion. Leigh et al. examined the costs of occupational diseases and injuries across the United States (28). They found that occupational diseases and injuries cost the United States US$ 250 billion each year. Direct medical costs accounted for 38% of this total, while the remainder was the result of indirect health-related costs.

**Human Costs.** Diseases caused by environmental pollution impose a heavy and unnecessary load on health care delivery systems in poor countries that already are facing a human resources crisis in the health sector. These costly diseases increase hospital staffing needs and thus divert resources from essential prevention programmes such as childhood immunizations, infection control and maternal and child health.

**Diminished economic productivity.** In societies where the brains, lungs or other organ systems of large numbers of persons have been damaged by widespread environmental pollution, the economic productivity of entire countries can be diminished. For example, widespread exposure to lead in countries that utilized leaded gasoline and thus suffered widespread low-grade lead poisoning with cognitive impairment is estimated to have reduced population mean IQ in those countries by about five points.

This downward shift in cognitive function across the entire population had the effect of reducing by more than 50% the number of persons with IQ scores above 130 – people who in the potential to be future leaders – and at the same time increasing by more than 50% the number of persons with IQ scores below 70, many of whom will impose a lifelong human and economic burden upon their societies (29) (Figure 3). Such widespread cognitive impairment can reduce the intelligence and lifelong economic productivity of entire generations thus undermining the developmental trajectory of entire societies.

**Loss of irreplaceable environmental treasures such as the Everglades or the Black Forest that are beautiful treasures in their own right and that have the potential to be current or future sources of revenue from tourism.**

**Costs of environmental clean-up.**

**Pollution can be controlled**

High-income countries have identified and controlled many of their worst problems of environmental pollution. They have developed practical, cost-effective and replicable control strategies to control environmental and occupational disease. These strategies succeed principally by controlling exposures at source. Lead has been removed from gasoline. Asbestos use has been sharply curtailed and in some countries banned. Air and water pollution have been reduced. Highly toxic pesticides have been replaced. These actions have produced tangible benefits for health. These strategies can be utilized in LMICs.

**Pollution control is highly cost-effective**

Control of environmental pollution has been shown to yield great economic benefits. Grosse et al. studied the economic benefits of removing lead from the United States’ gasoline supply (30). They found that from 1976 to 1999, the total decline in mean blood lead level in United States children aged 1–5 years that resulted from the removal of lead from gasoline was 15.1 micrograms/dL. From published data on the relationship between blood lead levels and IQ scores, they calculated that this decline in lead levels had produced a gain in the mean IQ score of United States children of between 2.2 and 4.7 points. Because each IQ point increases mean economic productivity over a lifetime by 1.76–2.38%, the authors estimated that the removal of lead from gasoline had generated an economic benefit in each year’s birth cohort since the 1990s of US$ 213 billion (range US$ 110 to US$ 318 billion).
Thus the aggregate economic benefit over two decades of removing lead from gasoline was more than US$ 3 trillion.

Based on that experience, lead has now been removed from the gasoline supplies of more than 150 countries around the world. However, in LMICs, lead continues to be a significant burden on societies, with exposures occurring from battery recycling throughout the world (31), and from exposure to leaded glazes in pottery in certain countries, including Mexico (32).

Pollution has not received the attention or investment it deserves

Given the great impact of pollution on health and health resources and the high cost-benefit of pollution prevention, efforts to mitigate pollution should become a key strategic priority for international funders and for LMIC governments.

Yet despite its global importance and amenability to prevention, environmental pollution has not received the priority it deserves in the international development agenda (32). Although international aid through the Global Fund for HIV, Malaria and Tuberculosis exceeded US$ 28 billion in 2013 (34), less than US$ 100 million in international aid resources are directed each year toward the control of pollution. This lack of attention in the programme priorities of major international organizations is striking. It is especially startling, given the substantial impact and favourable cost: benefit ratio of pollution control programmes. The likely reason for this lack of attention is a lack of awareness of the scope of the problem, as well as real uncertainty about where to begin to address this complex set of problems.

Why should wealthy countries care about pollution in poor countries?

The increasing interconnectedness of countries around the world provides one rationale for dedicating more resources to controlling pollution in poor countries at its source. With globalization, the health and environmental problems of any country have the potential to rapidly become the problems of many other countries. This potential has been graphically illustrated by the recent spread of the West African Ebola Virus epidemic. The principal reason that Ebola spread uncontrollably in West Africa and then jumped to Europe and the United States was that health systems in the affected countries of Liberia, Guinea and Sierra Leone were seriously weakened by years of war, neglect and insufficient local and international investment and thus were not able to contain the disease. A similar situation is seen in the case of environmental pollution. Contaminated air from China now travels across the Pacific and can be measured in countries around the Pacific Rim including the countries of North America. Mercury from gold mining and coal plants crosses international boundaries and can be found in global stocks of fish. Arsenic has been found in imported rice.

A second reason that rich countries should care about pollution in poor countries is that in their role as international donors who invest in strengthening health systems in poor countries, the world’s wealthy countries want to see a strong return on their investment. Pollution control can yield highly favourable return on investment and thus represents a cost-effective deployment of development dollars. By contrast, rampant pollution that undercuts the effectiveness of health care delivery systems in poor counties diminishes return on development investment.

A third reason to invest in pollution prevention is to assist poor countries to achieve optimal trajectories of development that contribute to reductions in poverty and to the calming of civil unrest. Widespread pollution that degrades the environment, undermines societal development and social cohesion, and condemns future generations in poor countries to continuing poverty and endless poor health encourages social unrest and catalyzes forced migration and war.

A final argument for prioritizing the prevention and clean-up of toxic pollution in the international development agenda is that pollution control will mitigate some aspects of climate change such as carbon black emissions and reduce threats to biodiversity.

Conclusion

LMICs are beginning to request international support to clean up their pollution. International development assistance that supports training, capacity-building and technology transfer provides a means for achieving this goal. But to be effective, pollution control programmes need to be assigned high priority in the international development agenda. They need to move beyond their current limited foci on mercury, toxic pesticides and protection of the ozone layer. And most importantly, they need to be adequately funded.

The good news is that pollution can be controlled. High-income countries have created public health and environmental protection programmes, and they have identified and controlled many of their worst environmental problems. They have developed practical, cost-effective control strategies to control environmental and occupational disease. These strategies succeed by controlling exposures. Lead has been removed from gasoline. Asbestos use has been sharply curtailed and in some countries banned. Air and water pollution have been reduced. Highly toxic pesticides have been replaced. These actions provide a blueprint that can be replicated in developing countries.

High-income countries are now in a position to transfer know-how, technology and funding to LMICs to help control pollution. Clean technologies and strategies for green growth that have been developed in rich countries can also be pursued by emerging economies. Early adoption of these strategies by developing countries can help prevent repetition of the mistakes of the past and can prevent decades of future contamination.

Pollution prevention and control have produced tangible benefits for health in countries around the world. Pollution control has lifted the economies of entire nations (30). Knowledge-based organizations such as the Global Alliance on Health and Pollution (GAHP) are galvanizing resources to assist LMICs address priority pollution problems (15).

Pollution control will convey particular benefits to the health sector in LMICs. It will reduce the economic and human burdens on the health sector of high-cost NCDs such as stroke, heart disease and cancer. Reduction in incidence and prevalence of those diseases will reduce indirect health-related costs. And reduction in the frequency of NCDs will reduce hospital staffing needs and thus allow health care resources to be directed toward essential prevention programmes such as childhood immunizations, infection control and maternal and child health.

Pollution is not inevitable. It is a problem that is solvable in our lifetime. Assisting LMICs to prioritize prevention, through management of pollution, is a highly cost-effective way to reduce
the burden on limited health resources and accelerate national development.

Richard Fuller has an engineering degree from Melbourne University, and worked with IBM and others before a successful period as an entrepreneur in New York, focusing on sustainability. In 1999 he formed Blacksmith Institute (also known as Pure Earth), a non-profit committed to solutions to pollution problems in the developing world. He has also been the driving force behind the Global Alliance on Health and Pollution, a collaboration with World Bank, ADB, EU, UNEP, UNDP and many affected countries. He serves on a number of boards and advisory groups related to this field.

Dr Philip J Landrigan MSc, is a pediatrician and epidemiologist. He serves as Dean for Global Health and Ethel H Wise Professor and Chair of the Department of Preventive Medicine in the Icahn School of Medicine at Mount Sinai in New York. Dr Landrigan is an international leader in public health and preventive medicine. His pioneering research on the effects of lead poisoning in children led the United States government to mandate removal of lead from gasoline and paint, and his leadership of a National Academy of Sciences Committee on pesticides in children’s diets generated widespread understanding that children are uniquely vulnerable to toxic chemicals in the environment. Dr Landrigan’s work has helped to secure the passage of the Food Quality Protection Act in 1996 and the establishment of the EPA’s Office of Children’s Health Protection. Dr Landrigan has been a leader in developing the National Children’s Study, the largest epidemiological study of children’s health and the environment ever launched in the United States. He has been centrally involved in the medical and epidemiologic studies that followed the destruction of the World Trade Center on 11 September 2001. He has been a consultant to the World Health Organization many times.

References

19. Miller RW. How environmental hazards in childhood have been discovered: carcinogens, teratogens, neurotoxicants, and others. Pediatrics 2004 Apr;114 (4 Suppl):945-51.

40 World Health Organizations and Health Services Vol. 50 No. 4