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The Environmental Risk Transition and Changing Health in Low and Middle Income Countries

SARAH JEWITT and MATTHEW SMALLMAN-RAYNOR

Many low and middle income countries continue to experience a transition in the major causes of illness and death as they develop economically. Particularly rapid transitions have been witnessed in some countries of South and Southeast Asia and, to a lesser extent, sub-Saharan Africa over the last 20 years. This article draws on the closely related frameworks of the epidemiological transition and the environmental risk transition to explore the geographical dimensions of these developments.

It has long been recognised that societies experience a change in the underlying patterns of illness and death with the process of economic development. In general terms, economic development is associated with an overall reduction in all causes of illness and death, a shift in the dominant causes of illness and death, and a corresponding increase in life expectancy. These changes are encapsulated in the Epidemiological Transition model that was first proposed by Abdel Omran in 1971.

Ages of the Epidemiological Transition

Central to Omran's model is the proposition that economic development is accompanied by a long-term transition in the leading causes of death, from a profile dominated by infectious and parasitic diseases to one dominated by chronic and degenerative diseases. Three evolutionary stages to the model were envisaged by Omran:

(i) *The Age of Pestilence and Famine*, where high death rates due to infectious and parasitic diseases are punctuated by periodic 'mortality crises' arising from famines, wars and pandemic diseases;

(ii) *The Age of Receding Pandemics*, marked by a progressive reduction in death rates as infectious and parasitic diseases retreat from the population; and

(iii) *The Age of Degenerative and Man-made Diseases*, where death rates continue to decline to low and relatively stable levels, with chronic and degenerative diseases and other conditions of 'modern' society now forming the leading causes of death.

Different parts of the world have progressed through these stages at different times and at different rates. In Western Europe, the transition occurred over an extended period of several centuries (Figure 1). For many low and middle income (economically developing) countries, however, the transition was delayed until the mid-twentieth century and continues through to the present day.

FIGURE 1 NEAR HERE

Twenty-first Century Transitions

The World Health Organization (WHO) generates estimates of deaths in each of its member countries for the purposes of health policy development and resource allocation (Box 1). Table 1 is based on the most recent WHO estimates (GHE2019) and gives the global total for each of three major categories of death in 2019. The categories are defined in Box 1, with the first two categories corresponding to the principal causes of death in the early (category I) and late (category II) stages of the epidemiological transition. According to the estimates in Table 1, category II conditions of late transition accounted for almost three-quarters (73.63%) of all deaths worldwide; most of the remainder (18.41%) were due to category I conditions of early transition.

TABLE 1 NEAR HERE

National patterns

Figure 2 breaks down the information in Table 1 by country. Economically developing countries stand out as the primary focus of category I conditions, with the map highlighting the low and lower-middle income countries of sub-Saharan Africa (40% or more of all deaths) and South and Southeast Asia (20% or more of all deaths). This contrasts with the high-income countries of North America, Europe and Australasia where category II conditions account for the overwhelming majority (80% or more) of all deaths.

Box 1: WHO Global Health Estimates 2019 (GHE2019)

As part of its mandate to monitor the health situation in the world, the WHO generates estimates of deaths by cause in each of its 194 member states. These estimates are grouped into three broad categories of condition:

I. Communicable, including infectious and parasitic diseases, along with maternal, perinatal and nutritional conditions;
II. Non-communicable, including chronic diseases such as cancers, cardiovascular and cerebrovascular diseases, neurological conditions and substance (drugs and alcohol) use;
III. Injuries, both unintentional (accidents) and intentional (self-harm, interpersonal and collective, including those arising from military conflict).

The most recent estimates were released in 2020 as Global Health Estimates 2019 (GHE2019). The purpose of these estimates is to inform decision-making on health policy and resource allocation.

FIGURE 2 NEAR HERE

Changing patterns, 2000 to 2019

The maps in Figure 3 plot the change in the percentage of all deaths attributable to category I and II conditions in the period 2000 to 2019. In the space of two decades, the proportion of deaths due to category I conditions fell by 10% or more in many countries of sub-Saharan Africa and South and Southeast Asia (Figure 3A), with a corresponding increase in the proportion of deaths due to category II conditions (Figure 3B). These developments were particularly pronounced in the countries of South and Southeast Asia, with the largest reductions in category I conditions in Nepal (33.08%), North Korea (32.93%) and Bangladesh (27.64%).

FIGURE 3 NEAR HERE

The Environmental Risk Transition

Geographical changes in causes of death, such as those illustrated in Figure 3, imply a shift in the underpinning risks of contracting different diseases. The Environmental Risk Transition model was developed by Kirk Smith in the 1990s and builds on the epidemiological transition by providing a framework for understanding the environmental basis of these changing disease risks (Figure 4). The model outlines how, in low-income countries, environmental risks associated with poor access to water, sanitation and clean household energy occur primarily at the household level (Box 2). With increasing economic development, environmental risks such as ambient particulate matter air pollution (e.g. outdoor air pollution associated with industrial facilities) and lead exposure (associated with e.g. motor vehicles) tend to become more prevalent at the community level. This part of the model reflects the environmental Kuznets curve which suggests that environmental problems increase and later decline as economic growth proceeds. With further economic development, global-level environmental risks become more significant, with low income populations bearing the brunt of climate change risks such as temperature extremes, food insecurity and natural disasters.

FIGURE 4 NEAR HERE

Environmental risk and disability-adjusted life years (DALYS)

What is the evidence to support the environmental risk transition? Figure 7 uses the measure known as *disability-adjusted life years* (DALYs) to explore the matter. DALYs estimate the years of life lost due to disability and premature death from a particular health condition. They are plotted in Figure 7 for health conditions that are linked to each spatial level of the environmental risk transition in low, middle and high income countries.

FIGURE 7 NEAR HERE

Box 2: Household-level Environmental Risks and Sustainable Development Goals

Lower respiratory infections and diarrhoeal disease are the fourth and fifth most significant causes of death and ill health globally and rank second and third in low income countries. Household air pollution from cooking and heating homes with solid biomass fuels (e.g. wood, charcoal, dung or crop residue) contributes to illness and deaths from respiratory illnesses, cancers, and heart disease. Approximately three billion people rely on such fuels for cooking and heating. Sustainable Development Goal 7 aims to reduce the use of inefficient cooking systems like the one in Figure 5 and increase access to clean cooking fuels, stoves and household energy.

FIGURE 5 NEAR HERE

Diarrhoeal disease is strongly linked to poor drinking water, sanitation and handwashing facilities. Infants bear a disproportionate share of environmental risk linked to poor water, sanitation and hygiene access which is estimated to kill over 2,000 children daily; more than AIDS, malaria and measles combined. Almost 1.7 billion people lack basic sanitation systems, with almost 500 million defecating in the open. Around 2.3 billion lack adequate handwashing facilities and over 750 million lack basic drinking water services. The situation may worsen seasonally if water supplies dry up, freeze or if flooding restricts access and increases the risk of faecal contamination (Figure 6). A key target of Sustainable Development Goal 6 is to address deaths and ill health associated with diarrhoeal disease through the promotion of access to sustainably managed water, sanitation and hygiene systems.

FIGURE 6 NEAR HERE

(i) Household-level risks. A striking feature of Figure 7A is the decline in DALYs linked to water, sanitation and handwashing and household air pollution with increasing income level. Importantly, there has been a steady decline since 1990 in the proportion of DALYs attributed to these risks (Box 3). Due to reduced reliance on biomass fuels for cooking and household energy, DALYs linked to household air pollution have declined quite sharply (7.27% to 1.88%) in middle income countries while DALYs linked to water, sanitation and hygiene have fallen more in low income countries (from 15.28% to 9.54%) over the same period. This is consistent with the decline in deaths from category I conditions in many low and middle income countries (Figure 3A).

(ii) Community-level risks. Figure 7B shows how community-level environmental risks have tended to worsen before improving as countries progress to higher levels of economic development. The proportion of DALYs linked to ambient particulate matter air pollution rose in low and middle income countries (by 1.41% and 2.93% respectively) between 1990 and

2019 but fell (by 1.3%) in high income countries. DALYs linked to lead exposure show a similar, if less pronounced, pattern. This is consistent with the increase in deaths from category II conditions in low and middle income countries (Figure 3B).

(iii) Global-level risks. Estimates of the proportion of DALYs linked to global-level environmental risks are currently limited to measures of high and low non-optimal temperature. Importantly, these estimates do not capture the health impacts of changing crop yields, extreme weather, sea level rises and changes in disease vector distribution. High optimal temperatures are linked to 0.46% of DALYs globally with Figure 7C identifying higher levels in low as compared to high income countries. Low optimal temperatures account for 1.03% of DALYs globally, with Figure 7C identifying greater impacts in higher as compared to lower income countries.

Box 3: Declining Household-Level Risks: Case Studies from India and Nepal

In India and Nepal, the proportion of DALYs attributed to household air pollution and poor access to water, sanitation and hygiene fell dramatically between 1990 and 2019. Risks linked to household air pollution declined further in India while Nepal made greater reductions in water and sanitation-related risks. Both risk categories remain high in remote rural areas with limited healthcare and infrastructure access plus elevated poverty, malnutrition and infant mortality levels.

In parts of Amravati District, Maharashtra in central India (Figure 8), diarrhoea accounts for 3-4% of deaths among adults and 10% among children. Cultural preferences for open defecation, combined with poor access to clean water and soap, facilitate the transmission of diarrhoeal pathogens along five environmental pathways: food, fluids (water), flies, fields (or soil) and fingers (the 'five Fs'). Illness and deaths from diarrhoeal disease rise in the rainy season as wet weather assists transmission via fluids and flies. Illness from household air pollution is also widespread as most people cook with wood (Figure 5) that they gather free of cost from nearby woodlands.

FIGURE 8 NEAR HERE

In Kavrepalanchok District, Nepal (Figure 8), the uptake of small-scale biogas systems has helped to address household air pollution and sanitation-related risks as they produce clean cooking fuel from animal manure and other organic matter including latrine waste (Figure 9). A complete shift to clean household energy is hindered by a reliance on wood for heating homes in winter and the use of additional (often very smoky and inefficient) stoves to cook larger meals plus food for cattle.

FIGURE 9 NEAR HERE

Risk overlaps

During the course of the environmental risk transition, people in low and middle income countries may find themselves in zones of 'risk overlap' where they experience both household and community scale environmental risks. Polluting industries located close to densely populated (but poorly serviced) urban areas may put large numbers of people at the centre of the risk transition. Here, they face a dual burden of high (although falling) household-level risks and increasing community-level risks. Such groups may also experience health risks associated with global climate change, creating a triple risk overlap.

Conclusion

Household-level environmental risks account for a significant proportion of deaths and ill health among the poorest by virtue of where they live. The impacts are especially pronounced among young children. Financial insecurity often limits access to decent housing and the infrastructure needed to supply sanitation, clean water and energy. Unaffordable healthcare may hinder recovery from exposure to environmental risks and this may further limit income-earning opportunities. As World Health Organization data indicate, however, the poorest tend to benefit most from improvements in environmental health. Relatively small gains in access to vital services like clean drinking water, energy and sanitation can significantly reduce the burden of ill-health and death faced by the poorest and the youngest. This in turn translates into improved life expectancy, lower infant mortality and livelihood benefits as fewer days are lost to sickness.

Autobiography

Sarah Jewitt and Matthew Smallman-Raynor are professors in the School of Geography at the University of Nottingham. Their research interests include health and disease, development and the environment.

Key points

- Many low and middle income countries continue to experience a transition in the major causes of illness and death as they develop economically. Particularly rapid developments have been witnessed in some countries of South and Southeast Asia and, to a lesser extent, sub-Saharan Africa over the last two decades.
- The Environmental Risk Transition model provides a framework for understanding the environmental basis of changing disease risks with the process of economic development. As societies develop economically, the spatial scale of environmental risk increases from the household level to community and global levels.

- The poorest tend to benefit most from improvements in environmental health. This in turn translates into improved life expectancy, lower infant mortality and livelihood benefits as fewer days are lost to sickness.

Questions for discussion

- What factors influence the relative levels of communicable and non-communicable diseases in a population?
- In what ways may household-, community- and global-level environmental risks intersect to yield poor health outcomes?

Glossary

Biomass Organic matter (including wood, crops and agricultural residue, manure and household waste) that is used as an energy source.

DALYs Disability-adjusted life years, a measure of the years of life lost due to disability and premature death from a particular health condition.

Degenerative disease A disease associated with the progressive degeneration of tissues or organs that is linked to factors such as aging, genetics or lifestyle

GHE2019 Global Health Estimates 2019, a World Health Organization (WHO) database of global, world regional and national trends in illness and death, 2000–2019.

Pestilence A deadly occurrence of communicable disease.

World Health Organization (WHO) The agency of the United Nations (UN) responsible for international public health.

Further reading

'People in Africa are living longer but lifestyle diseases are rising', *The Conversation* (October 2016): https://theconversation.com/people-in-africa-are-living-longer-but-lifestyle-diseases-are-rising-66686

The Institute for Health Metrics and Evaluation (IHME), Global Burden of Disease (GBD): https://www.healthdata.org/gbd/2019

World Health Organization (WHO), Global Health Estimates: Life Expectancy and Leading Causes of Death and Disability: https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates

Figure 4 is a schematic representation of the Environmental Risk Transition framework as outlined by Kirk Smith and Majid Ezzati:

https://www.annualreviews.org/doi/abs/10.1146/annurev.energy.30.050504.144424

Table 1. Estimated number of deaths worldwide in 2019, based on GHE2019

Category of death[1]	Estimated deaths (000s)	Proportion of all deaths (%)
I (communicable, maternal, perinatal and nutritional)	10,201.4	18.41
II (non-communicable)	40,804.8	73.63
III (injuries)	4,409.6	7.96
Total	55,415.8	100.00

[1] See Box 1 for a description of categories.

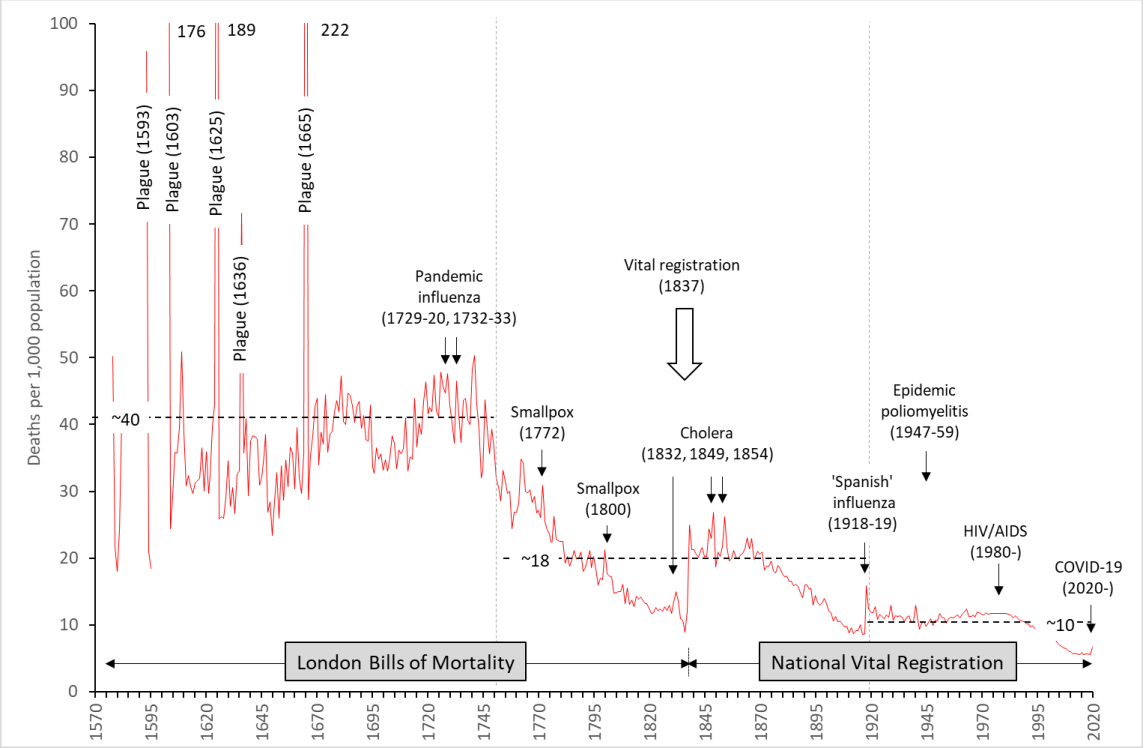

Figure 1. Changing death rates in London, 1570–2020. The main stages of the epidemiological transition are indicated, as are some noteworthy epidemics of infectious diseases. Note the extended nature of the transition over several centuries and the towering mortality crises due to plague in the early decades.

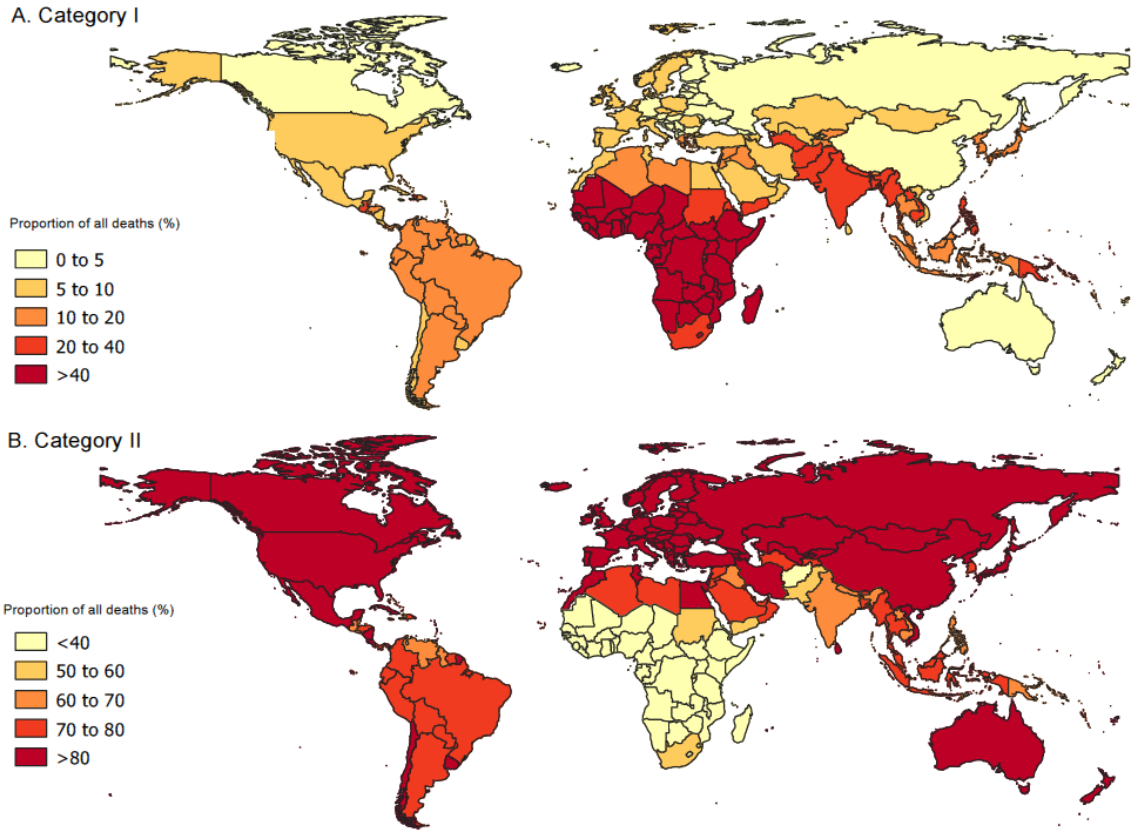

Figure 2. National-level estimates of the percentage of all deaths due to (A) category I (communicable, maternal, perinatal and nutritional) conditions and (B) category II (non-communicable) conditions in 2019.

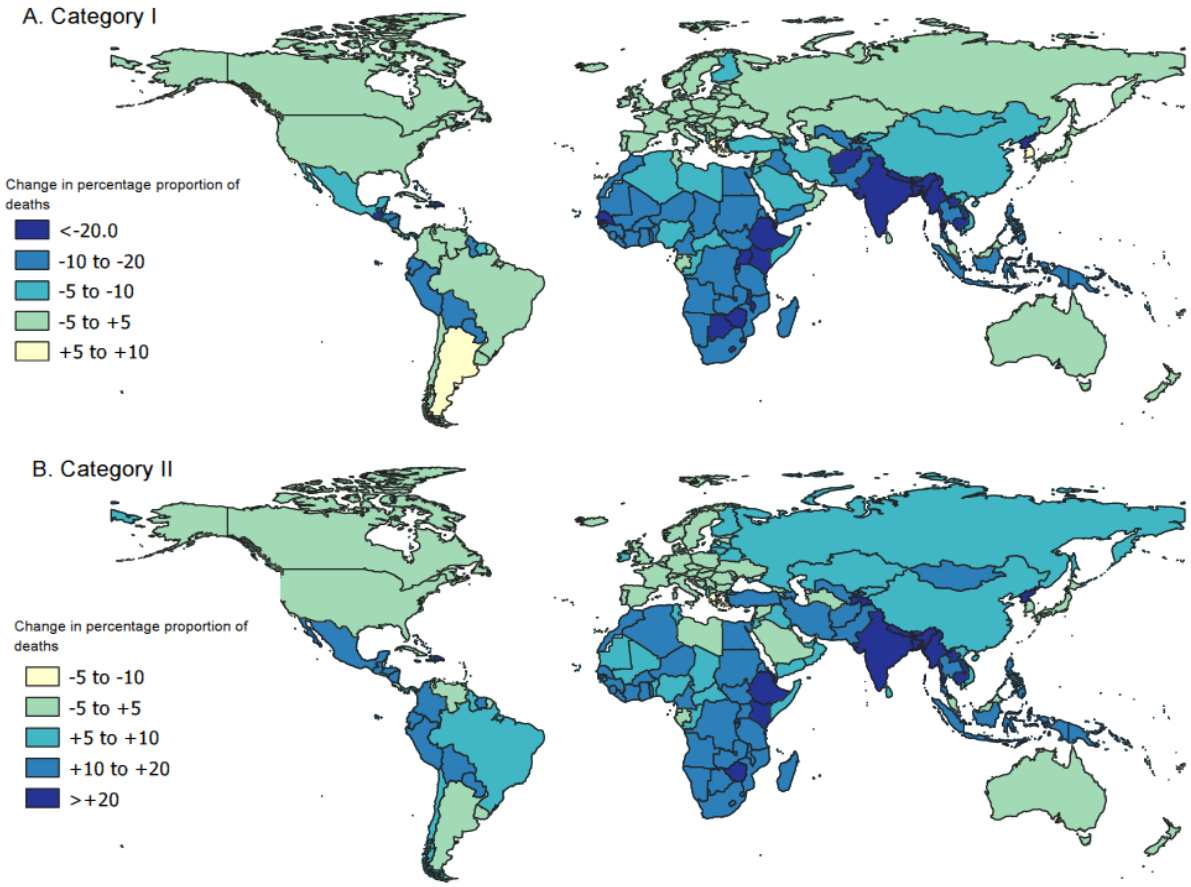

Figure 3. National-level changes in the percentage of all deaths due to (A) category I (communicable, maternal, perinatal and nutritional) conditions and (B) category II (non-communicable) conditions. The changes are measured over the period 2000 to 2019. Note the many negative values in map (A). These indicate a reduction in the proportion of deaths due to category I conditions.

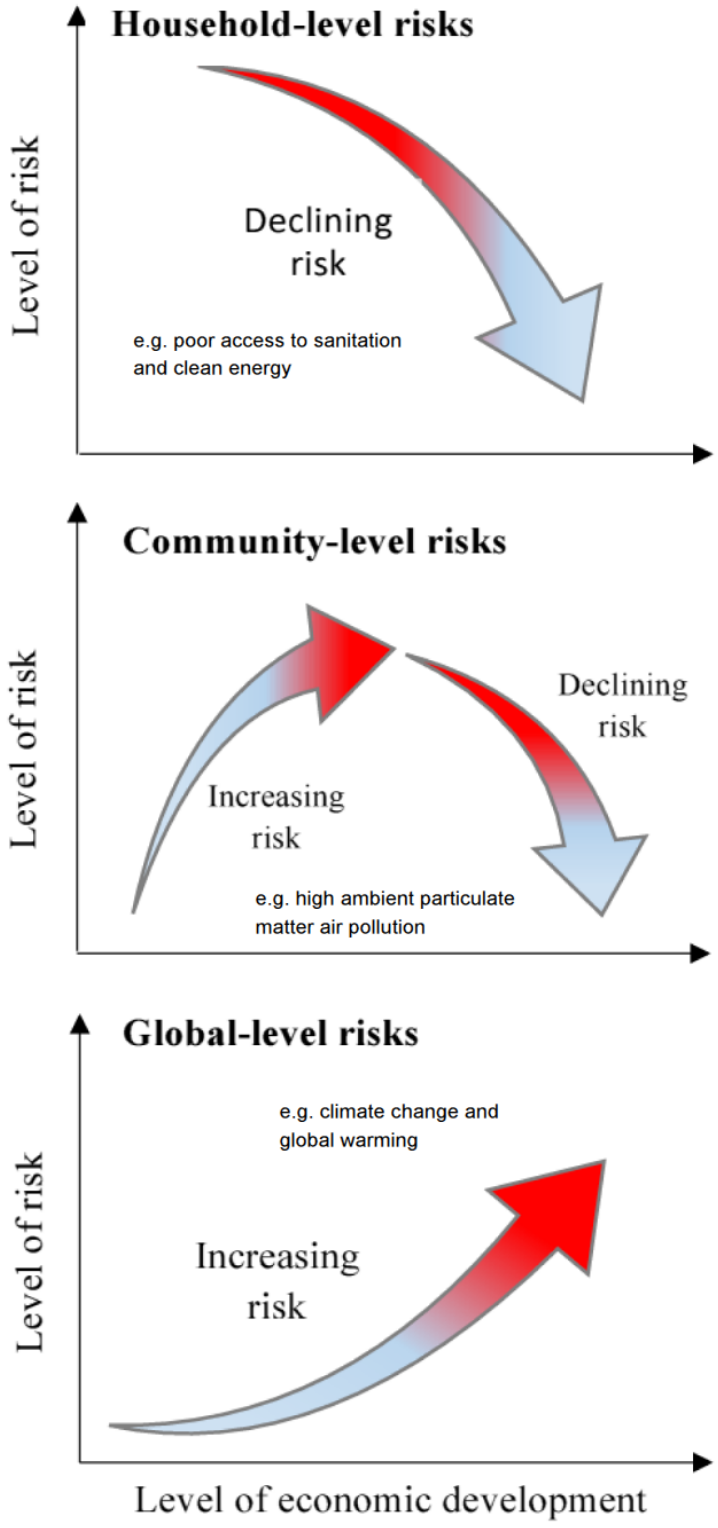

Figure 4. Smith's Environmental Risk Transition model illustrates how increasing economic development is accompanied by declining household-level environmental risks (upper graph), a rise and subsequent fall in community-level environmental risks (central graph) and a longer-term growth in global-level environmental risks (lower graph).

Figure 5. This wood-fuelled open fire in Amravati District, central India is typical of the cooking and heating systems used in many low and middle income countries. Although wood and other solid biomass fuels can cause high levels of household air pollution and associated respiratory problems, the adoption of cleaner fuels is often hindered by a lack of energy infrastructure or an inability to afford connection costs or ongoing bills. *Source*: the authors.

Figure 6. This toilet near Guwahati, northeastern India, gets flooded for 2–5 months per year. During this time, its owners have to defecate in the open or share their neighbour's toilet which is built on higher ground. Open defecation is strongly associated with diarrhoeal disease which remains one of the most significant causes of ill health and disease in low income countries. *Source*: the authors.

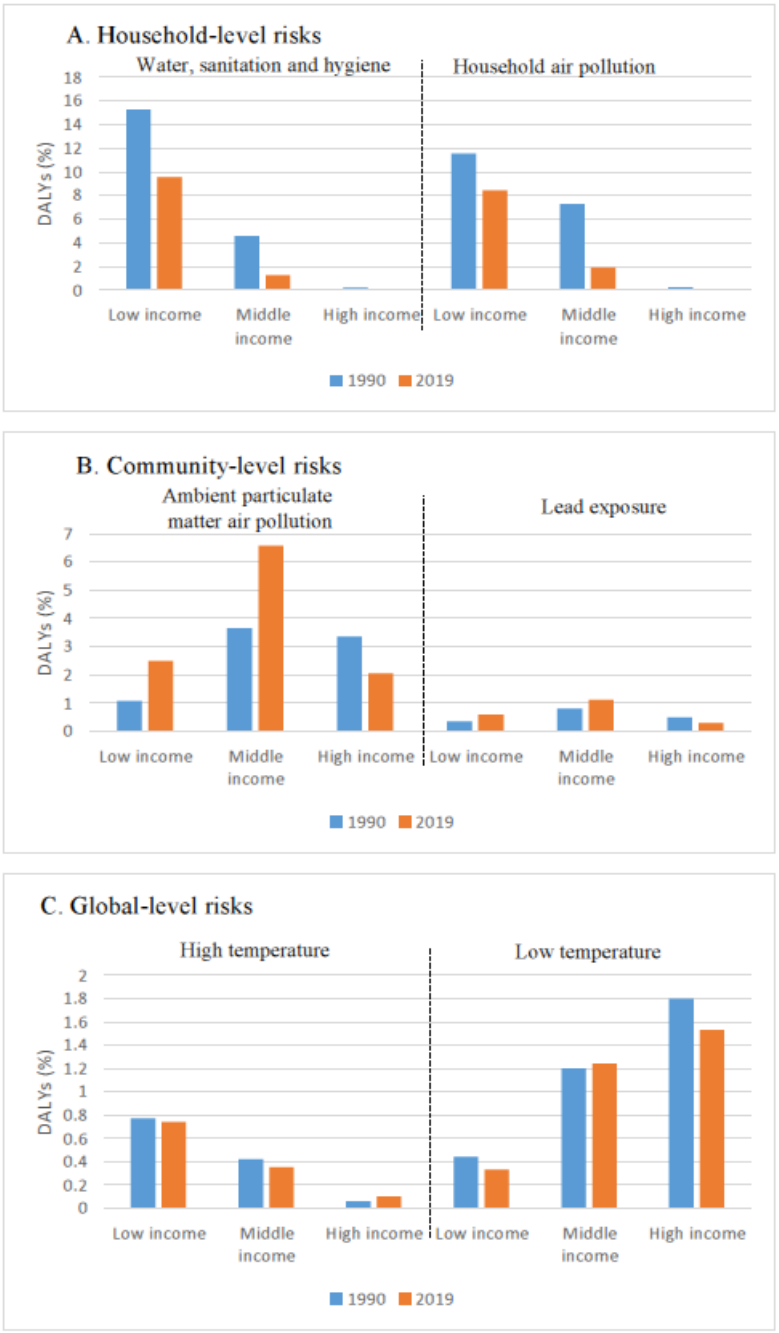

Figure 7. The proportion of disability-adjusted life years (DALYs) attributed to environmental risks in low, middle and high income countries in 1990 and 2019. Graph (A) shows declining household-level risks associated with water, sanitation and handwashing and household air pollution across all age groups and income levels. Graph (B) shows community-level risks linked to ambient particulate matter air pollution and lead exposure rising and later falling with increasing income. At the global level, graph (C) highlights variations in DALYs linked to high and low optimal temperatures by country income group.

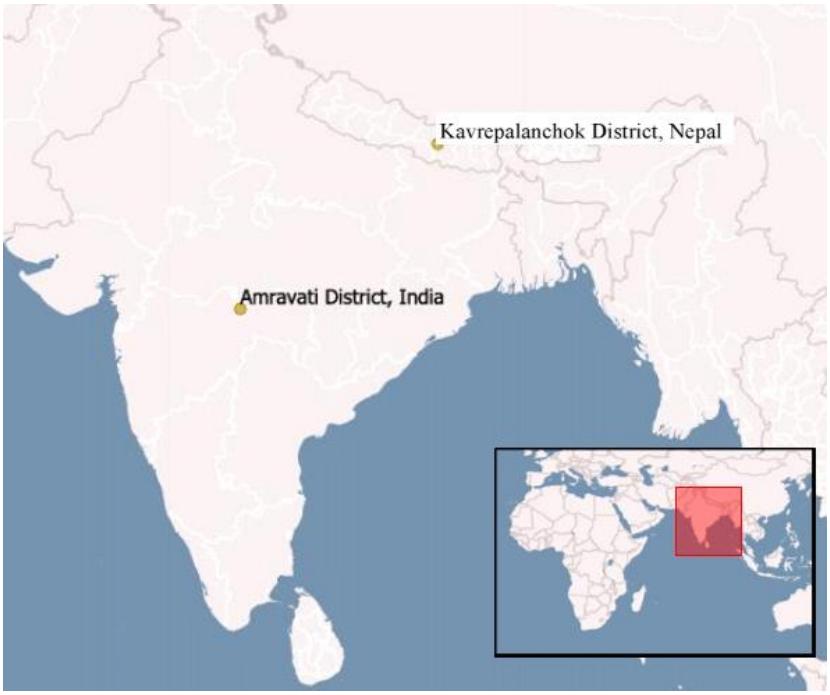

Figure 8. Location of case study sites in India and Nepal, South Asia.

Figure 9. This biogas stove in Kavrepalanchok District, Nepal is fuelled by clean energy generated from household and animal waste. In addition to cooking gas, the biogas system produces digestate that can be used as fertiliser.