Making a Difference:

Indicators to Improve Children's Environmental Health

WORLD HEALTH ORGANIZATION
2003

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Indicators to Improve Children's Environmental Health

Prepared on behalf of the World Health Organization

by

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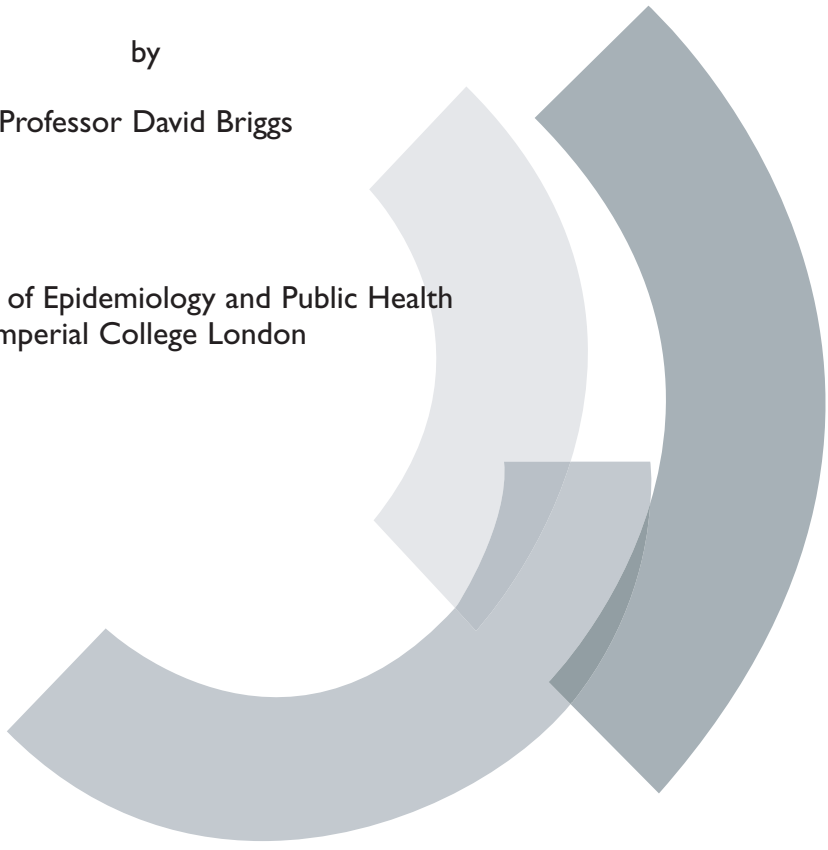

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PREFACE

Over the last ten years considerable effort has been devoted to developing environmental health indicators to support policy. In only a few cases, however, can the material effects of these indicators, in terms of reduced health inequalities or mortality rates, be seen. In many cases, this is because the problems are intractable and complex. Long latency times mean that it will take many years for the effects of interventions to become detectable. In other cases, it is because the indicators themselves have not been especially relevant or applicable.

Recognition is now growing that our first priority should be the very young, not only because they are often the most vulnerable and least able to help themselves, but also because it is often the events that happen in the early years that shape the rest of their lives. Early intervention can thus have lifelong benefits.

Early intervention, however, requires rapid recognition of what needs to be done, followed by quick and targeted action. In this context the need for effective indicators becomes all the more acute. The purpose of this report is to lay the foundation for developing and implementing these indicators as a basis for priority setting and action.

The report does two things. It discusses and describes some of the principles that need to be considered in developing effective environmental health indicators for children. It then applies these to produce a set of indicators, targeted at the main disease burdens that affect children globally (CD-ROM).

The indicators presented here are intended to serve several purposes. Amongst others, these include:

- providing a basis for assessing environmental risks to children's health, in order to help prioritize policy at national and global level;
- acting as a basis for monitoring and evaluating the effectiveness of national and international initiatives to reduce environmental health risks for children;
- providing a template for developing other indicators as needed to address issues of specific local or national concern.

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David Briggs
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1. INTRODUCTION

1.1 Children in an adult world

Children, like other unempowered and vulnerable groups, are all too often the victims of the environment, and the way we manipulate it to serve our adult ends. They lose their lives more often in natural disasters, they are the innocent victims of war, they are more likely to be injured or maimed on the roads, and they are more frequently and severely afflicted by a wide range of respiratory, gastro-intestinal and vector-borne diseases. There is no ambiguity or area of debate in this. Data may often be lacking and in many countries (often those where the problems are worse) monitoring is far from adequate, but the numbers involved are such that any uncertainties matter little. Count them how we will, every year millions of children die, are disabled and endure suffering that could be avoided. Globally, children are leading impoverished and damaged, often grotesquely shortened, existences, and all because of the world in which they find themselves, because of their environment.

This vulnerability in the face of environmental, and associated social, threats is not solely a matter of diminutive stature or biological immaturity, nor even of their specific behaviours and unawareness of risk. It is also, fundamentally, because they are children in an adult world. It is because they are powerless to mould their own environment or command their own destiny — even to avoid the risks that confront them.

If children are to be better protected, therefore, they must rely on adults to shape a more benign and safer world for them. And if adults are to do this task effectively, they need to see the world through children's eyes, to recognize the threats faced by children, to understand the child's helplessness in the face of these threats, and to be more aware of the way their own adult decisions and actions impinge on that world.

This is no easy challenge. The ability to see the world through the eyes of others — even our former selves — is weakly developed, especially when the voice of those others is muted or silent. This voicelessness is a characteristic of almost all weak and vulnerable groups — not only children, but the elderly and poor alike. In the case of children, however, it is especially marked. Even in the best democracies, children (at least those under 18 or so) have no vote; they control no newspapers or TV stations and command no budgets for advertising; they cannot organize protests or strikes; they cannot petition or challenge decision-makers in court. They depend wholly on the decisions and laws of adults, yet have no means of communicating their concerns to those who decide or of promoting their interests with them. And more often than not, of course, they cannot even grasp what these concerns or interests are.

1.2 The need for information

The voicelessness of children, at least in terms of the formal processes of politics and power, will not greatly change: children will not become decision-makers, policy-makers or lobbyists in their own right. If the threats to the lives and health of children are therefore to be properly addressed, decision-makers need other forms of help and guidance. They need clues to the issues that matter for children, an indication of the hazards and risks that need to be addressed; they need help in prioritizing and evaluating actions in relation to and on behalf of children in ways that put children first. They need clear, relevant, and unignorable information about the things that affect children's lives.

Who are children?

Age is clearly the defining characteristic that separates children from adults. Defining children in terms of their age, however, poses major problems, and different definitions have been adopted by different countries and international agencies. The WHO's Department of Child and Adolesecent Health and Development defines children as under 20 years of age. The Convention on the Rights of the Child defines them as under 18 years of age.

In reality, no simple definition by age will suit every circumstance. As children grow and mature, they change dramatically — and so do their patterns of risk. Even children of the same age and gender may vary enormously in terms of their physical characteristics, cognition and behaviours, depending on their circumstances and fortunes. Differences in the way we treat and care for children in different cultural contexts, help to produce marked differences in the way children are seen, and see themselves, in different parts of the world.

In considering the threats to children, therefore, we need to be adaptive. We need to recognize that who is at risk varies from one place and one risk factor to another. In this context, we focus on children between the ages of 0 and 14, because it is at these ages that the risks tend to be greatest. For many indicators, however, we use an even narrower age band (0–4) since it is these who are often especially vulnerable.

1.3 Indicators

One way of providing this information is through indicators. In recent years the use of indicators has grown rapidly in many different fields, including economics, environment and health. The extent to which the use of indicators has improved decisions and enhanced the world is, admittedly, a moot point. Certainly they are no panacea. Too often, they have been seen as an easy solution: a way of highlighting the problems that confront us and learning how to respond, without the cost or inconvenience of having to collect or analyze data, or really to understand. This is inadequate, for if indicators are to tell us anything, it is only because they are based upon reliable and often hard-won data, and are interpreted with sense and equally hard-won understanding. All too frequently, however, they merely provide decision-makers with the false assurance that they know what is happening and have done the right thing. At best this is neglectful. At worst it is deceitful, in that it represents a deliberate attempt to cover up realities and use information simply to promote self-interest.

In some cases, more positively, indicators are held up as warning signals to alert us to dangers that would otherwise not be foreseen. For the most part, however, this is likely to be more a hope than a reality. For indicators are only likely to be developed and used if we have already defined a need to know; and recognizing the need to know means that we are already alerted. Usually, therefore, indicators follow rather than precede awareness, providing answers to questions already posed. They allow an assessment and tracking of known issues but rarely offer a warning of new problems. Such questions about new concerns tend to emerge in other ways. Sometimes they are the result of obvious events — for example, outbreaks of disease or major catastrophes, detected not through formal indicators but through routine monitoring and management. Sometimes they arise from chance insights or observations of previously unnoticed patterns or associations — for example, apparent clusters of disease or connections between a putative hazard and a health effect. Quite commonly, they develop as a result of independent, exploratory science and research, either involving the collection of new data or through the analysis of data that already exist.

Indicators, however, can and sometimes do serve a number of important purposes. Constructed properly, founded on real understanding, based on good data and good science, they can be used to monitor situations that might affect us, or to track the effects of specific interventions. Once we have identified an issue, therefore, indicators can reassure or forewarn us; once we have tried to act, they can help us to judge our performance against the goals we hope to achieve. Similarly, they can be used to compare conditions or achievements in our own country or community with those of others. Thus, in the hands of empowered (and especially passionate) people, they can also be powerful symbols: they can be used as a way of highlighting issues and concerns, and of bringing these to the attention of those who need (but often do not want) to know.

Two uses of indicators thus stand out — they are instruments for lobbying and awareness raising, and they are tools for self-judgement and for assessing how well we perform. In the case of the health of children, both these applications are of utmost importance. The very persistence of threats and damage to children, often on an unforgivable scale, underlines the need to challenge those responsible (whether by commission or omission) unequivocally. The requirements for action — and, indeed, the wide range of actions already being taken, some to the benefit, but many to the detriment, of children — likewise demonstrate the need to be able to monitor and assess our actions in relation to children's welfare. The set of environmental health indicators developed here is meant to serve these needs.

What are indicators?

Indicators are signals for things that cannot be directly seen. They are based on data, but ideally add value to data by expressing them in a way which is more understandable and more relevant to the user.

It is often said that monitoring provides data, analysis of data provides statistics, and interpretation of statistics provides indicators that help to inform decision-makers.

Even so there is much confusion about what indicators are. Mistakenly, they are sometimes regarded as the *issues* that we need to address (e.g. indoor air pollution, respiratory health). Equally misleadingly, they are sometimes defined as the values that we obtain when we try to quantify these issues (e.g. 175ug/m^3 PM_{10}, or a respiratory mortality rate of 98.5 per 100 000 births). In practice they are neither. Indicators are about the things that lie between the two: they are the entities that we try to measure (e.g. mean annual PM_{10} concentration or mortality rate) to describe the issues that we are concerned about in a clear and understandable way.

That said, some confusion is inevitable, for there is no clear distinction between data, statistics and indicators. Child mortality rate, for example, can be any one of these things. What makes it an indicator in some situations is not the measure itself, but its purpose and the way it is used.

What are environmental health indicators?

Environmental health indicators have been defined as:

- *an expression of the link between environment and health, targeted at an issue of specific policy or management concern and presented in a form which facilitates interpretation for effective decision-making.*

Source: Corválan et al. 1996

2. DEFINING WHAT MATTERS

The global burden of disease

The Global Burden of Disease (GBD) represents the sum of life-limiting disease on the human population. The original assessments were made by Chris Murray and Alan Lopez, in 1996. In the original assessment of the GBD, the environmental contribution to the global burden of disease was deduced by attributing mortality and morbidity data to environmental causes, mainly on the basis of expert opinion, and by extrapolation from research studies. Since then, a more detailed analysis of the global burden of disease is being undertaken, which is attempting to assess the environmental contribution to the GBD from estimates of population exposures and exposure-response relationships (Ezzati et al. 2002).

Because the overall effect of illness and disability cannot realistically be assessed only in terms of the death rate, and because comparisons cannot easily be made between crude rates of morbidity (which may differ greatly in severity), the GBD is estimated in terms of disability-adjusted life years (DALYs). These are a measure of the years lost to either premature death or life-limiting disease.

No indicator tells us all we need to know: the world and what we need to know are both too complex for that. Nor can we develop indicators for everything. If we were to do so, the huge volume of information — much of it often contradictory and confused — would simply weaken rather than strengthen the message, and overwhelm those concerned. Or the indicators themselves would be so wide-ranging and general that any meaningful interpretation would be impossible. To be effective, information must always be selective: we must target the key issues and communicate concisely.

Selection is not easy. Children are subject to many different threats, and these vary depending on local circumstance and the vulnerability of those concerned. The range of potential issues of interest is therefore extremely large. In defining these issues, we also need to take account of both cause and effect. Not all health outcomes derive from the environment, but those that do can only be effectively addressed if we understand their environmental roots. Indeed, in terms of action and response, the focus should perhaps be on the environment rather than the health outcome: for while we can often reduce suffering by treating health outcomes, only by removing the exposures responsible for the disease can we avoid it entirely. This needs action far upstream of the health effect — for example, by intervening in the environmental processes, or the social and economic systems, that generate the hazard in the first place. By the same token, the fruits of intervention are often seen first in the environment, and only later — too late to ensure prevention — in the health of the population.

2.1 The burden of disease

By selecting, of course we also prioritize. The issues we select as the focus for our indicators, therefore, become the focus for our policy. How then should we select?

The most obvious way is in terms of the burden of disease. In this context, what matters most for children is incontrovertible. Global estimates of the burden of disease, derived from an analysis of national statistics and research studies (Figure 1), are already available. Both the data and the science behind these estimates are admittedly approximate, but such is the scale of illness in the world that approximations matter little. The major causes of death and illness — and thus the major focus of concern — are all too evident. They dominate the statistics. Though they can be categorized in different ways, five main groups demand attention:

- Perinatal diseases — including low birthweight, stillbirths and congenital malformations.
- Respiratory diseases — including pneumonia, , tuberculosis and asthma.
- Diarrhoeal diseases — including rotavirus infections, E. coli infections, and cholera.
- Insect-borne diseases — especially malaria.
- Physical injuries — including traffic accidents, poisonings, drowning, falls and burns.

Together, these kill some 10 million children below the age of fifteen every year, of whom probably at least three-quarters are under the age of five (WHO 1996).

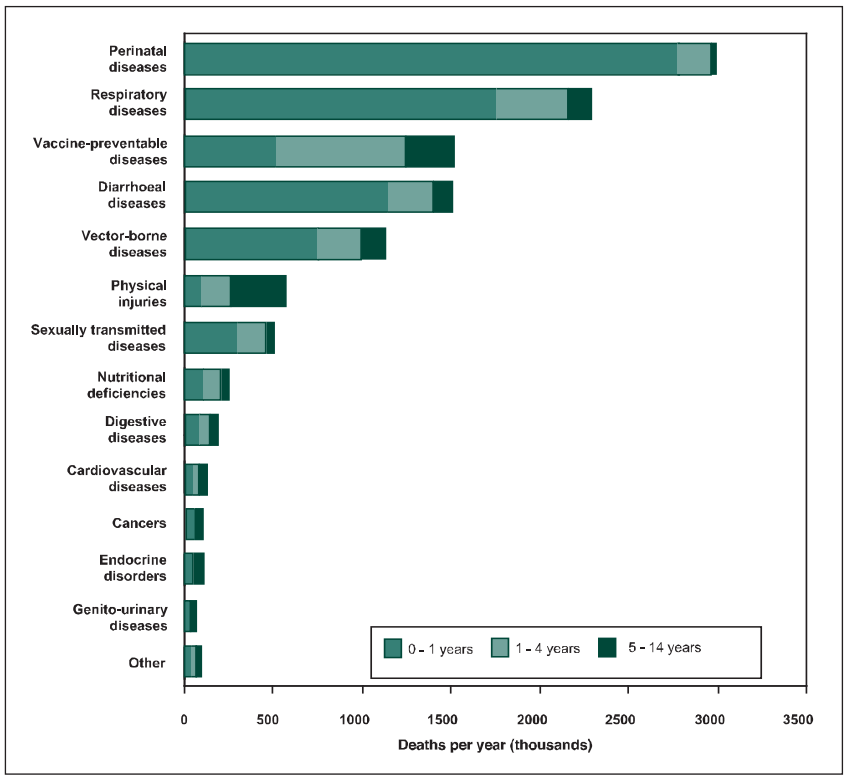


Figure 1. Global mortality rates by age for major categories of disease

The data show that, for most causes, the large majority of deaths occur to children during the first year of life. They also show that five main causes — perinatal conditions (together with congenital anomalies), respiratory infections, diarrhoeal diseases, malaria and physical injuries (including drowning and motor-vehicle accidents) are the major killers of young children.

Source: WHO 2002

These diseases are not the product of the environment alone. Genetics, lifestyle, and chance play a large role, but the exposures to environmental hazards certainly make a major contribution. Thus, their prevalence depends to a large extent on conditions such as the magnitude of natural hazards, the extent and severity of pollution, and the quality of the living environment. Together, these five disease groups account for about one-third of the total global burden of environmental disease in children (as much as 40% of those aged less than five). By the same token, they are susceptible to environmental policy.

They are also, almost overwhelmingly, diseases of the developing rather than the developed world. With development they are all, more or less, avoidable. In selecting these issues as the focus for attention, therefore, we are inevitably skewing our efforts to the developing world. From a global perspective that is surely just, for it is in developing countries, overwhelmingly, that the largest burden of children's disease is found. Nonetheless the point must be made. The way we define the issues will inevitably limit the indicators we choose. And, if we use the indicators effectively to guide our actions, then these in turn will skew the way we act. The old adage is true: we manage what we measure and we measure what we manage.

We need, therefore, to be clear about how we select the issues for which our indicators are designed, and why we have selected them. We also need to recognize that, in another area, with different problems, or from the perspective of another observer with different interests, this selection may differ, and, with it, the choice of indicators also. Indicators are thus servants of need. They are rarely, if ever, universal. As the need changes, so must the indicators change. Any set of indicators, however 'core' they might be, is limited in its relevance and can easily be made redundant by changes in conditions or concern. For other purposes, and especially in the developed world, other issues might therefore need to be defined, and with them other indicators. As priorities for global concern, however, this 'big five' amongst the killers of children stands unchallenged. If we do not understand and do not better address these killers, then we will have failed indeed. As a basis for global action, they are surely priorities.

Traditional, modern and emerging risks

Children's health risks tend to change as a consequence of development. In less developed countries, 'traditional' environmental health risks tend to be associated with problems such as poor sanitation, unsafe food, malnutrition and vector-borne diseases. With economic development, many of these risks are eliminated or at least greatly reduced. In their place, new risks tend to emerge, such as exposures to pollution from industry and transport, and problems such as obesity. Most of these 'modern' risks can, however, be effectively controlled by implementing policies of sustainable development, in which environmental protection is linked to deliberate strategies to reduce inequalities and enhance education and empowerment. In addition, there are 'emerging' risks such as environmental allergens, endocrine disruptors and autoimmune diseases; potential health-and-environment linkages require further research to identify causative factors or a combination of such factors.

What is the environment?

Definitions can sometimes be the death of understanding. Rather than clarifying, they can simply confuse. So it is with 'environment' – a concept that means many different things to different people. In reality, the environment has no clear bounds. It simply means the context within which things happen: 'the conditions or influences under which any person or thing lives or is developed' in the words of the *Oxford English Dictionary*

In terms of environmental health, the environment thus includes not only the natural world, but also the anthropogenic world of the home, school, workplace and neighbourhood. It includes not only physical and chemical influences, but also the social and other factors that affect our health.

This is an expansive definition. If applied in full it throws open the whole world to our consideration. For practical reasons, we have to be more pragmatic. While we do not draw strict boundaries around the concept of environment, we do therefore define a focus for our attention. This focus is provided by the physical contexts within which children interact with their world: the ambient environment (the wider world of air, water, land and living creatures); the community (the social environment or neighbourhood within which they live); and the home environment.

Even in the developing world, these diseases do not affect everyone equally. Socio-economic disadvantage is in many ways the great divider. But age — and in many cases gender — are also powerful discriminators of risk. Usually, it is the youngest who are most under threat. Across the world, death rates are greatest in the first year (and often the first hours) of life.

Later in life, the balance of risks tends to change, and other risk factors emerge. In particular, injuries, and some infections such as measles, begin to take a greater toll. By age five, however, those who survive already have a greatly increased life expectancy. Even when they do not kill, many of the diseases of the very young also leave a lasting and, in some cases, lifelong imprint. These early years therefore hold the key.

2.2 The environment as hazard

Of course, all these deaths and diseases cannot be attributed, either directly or indirectly, to the environment within which children are born and live. Environmental agents nevertheless lie behind many of these diseases and disabilities, and in some cases — such as diarrhoeal diseases or vector-borne diseases — they clearly account for the major share of both mortality and morbidity.

In part this is because the environment is itself a hazardous place. Natural processes such as earthquakes, volcanoes, landslide, floods and droughts all pose threats. In many areas these threats are increasing, not because the hazards themselves are necessarily becoming more severe, but because human populations are moving into hazard-prone areas.

More generally, however, it is the way that humans use the environment that makes it a hazardous place to live. Pollution often provides the most obvious evidence for this. But damage to soils, abstraction of groundwaters and destruction of habitats all have equally far-reaching implications for health. We thus create new environments and vectors for insects and other carriers of disease, we change the hydrology and climate and increase the likelihood of droughts or floods, and we shift closer to the limits that the Earth can sustain.

The environment, therefore, is often not the villain, but merely the medium through which threats to health operate. Indeed, strictly speaking, many of the environmental health risks facing children derive not from the environment per se, but from the things humans do in, and to, their environment.

Human impacts on the environment are far-reaching, and are increasingly felt on a global scale. The threats they pose to children's health, however, are far more local. Children, even more than adults, spend most of their lives at home — 80% or more when very young (Tso and Yeung 1996, Farrow et al. 1997). It is in the home, therefore, that by far the largest majority of exposures and infections that afflict children occur. The home, however, nests within a neighbourhood, and is dependent on the services and support systems which the community provides (Figure 2). Inadequacies in these services (e.g. in water supply, food supply or waste collection) thus also threaten the child. By comparison, exposures in the ambient environment are often of relatively less importance for children, though on some occasions — as with major natural disasters or war — they can certainly intrude. Nevertheless, the wider environment remains vital, for it is here that many of the actions aimed at protecting children need to take place — for example, through national or international policy aimed at tackling the root causes of environmental health problems.

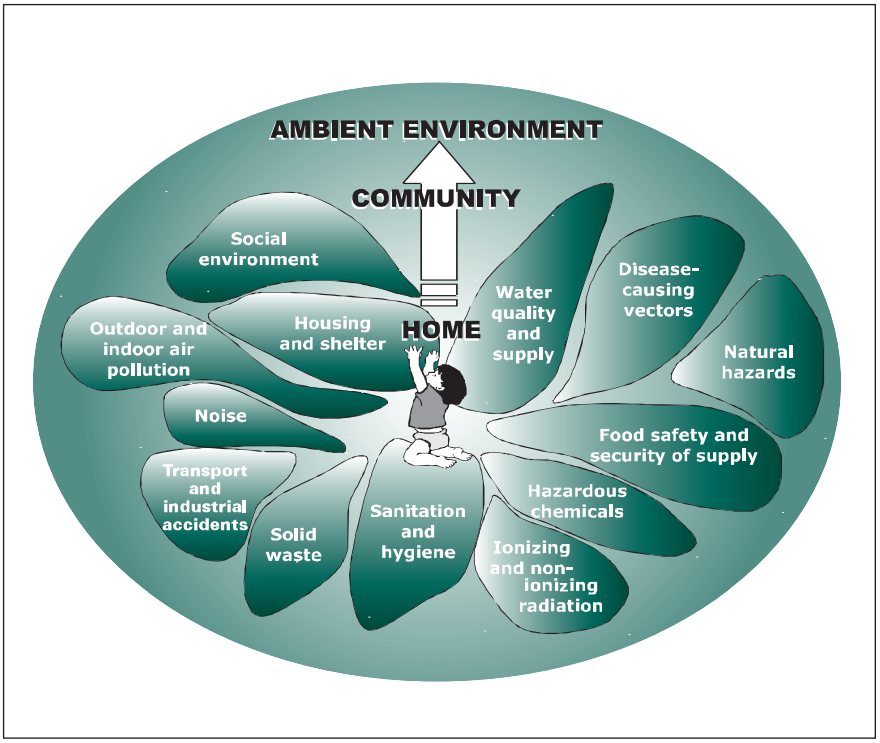


Figure 2. Children's hazard spaces

Children's exposures to environmental health hazards occur in many different settings – in the home, in the neighbourhood or community and in the wider environment. Most hazards operate at a range of spatial scales, and thus straddle the three settings of ambient environment, community and home. Because children spend most of their time indoors at home, however, it is in this setting that most exposures occur.

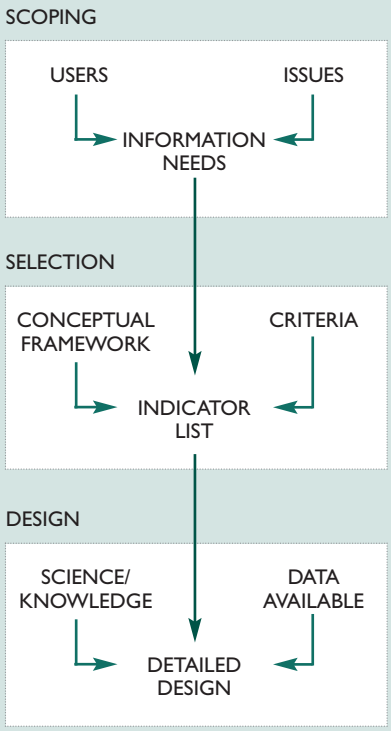
Source: WHO 2002

Against this background, we can argue that what matters to children is not the same as what matters to adults. One reason for this is that children occupy very different types of hazard spaces (i.e. the places where they spend their time and are most at risk). For adults, these spaces are typically diverse, though occupational environments are often especially important since they account for a large part of adults' activity time and are relatively hazardous. In contrast, children — and especially young children (who are inherently the most vulnerable) — occupy far more restricted hazard spaces.

Nor is it only the physical environment on which we should concentrate. The social world is also important. All children are not born equal, either in terms of wealth or opportunity. For almost all hazards and health outcomes, the gradient of risk per unit of exposure is greater for already impoverished children than it is for children from better-provided backgrounds or more affluent homes. The reasons are complex and many. Poorer households may be subject to a wider range of environmental hazards, both in the home and outside, which act, often together, to increase health risks. Parents and children from poorer homes are likely to be inherently more vulnerable because of problems of poor diet and lifestyle. They are likely to be less aware of how to cope with risks and less able to take avoiding or mitigating action; they have less access to education and health care. The physical and social environments thus act in consort not only to threaten the health and lives of children, but also to determine their vulnerability to these threats. Children are also inherently more vulnerable, not only because of their smaller stature, and their limited bodily defences, but also because of their lack of familiarity with many of the environmental hazards they face, their lack of command over any of these risks and their limited scope to avoid them.

3. TOWARDS A CORE SET OF INDICATORS

Figure 3. The design process



Building indicators — especially indicators that are effective and serve to improve children's lives — is not easy. Many different considerations have to be taken into account; many different constraints have to be addressed and resolved. A balance has to be struck between what is needed and what is practicable, between what is ideal and what will work.

These demands are not unique to developing indicators. They are much the same as those placed on any attempt at product design and development. In the world of engineering and commerce a more-or-less formulaic process has evolved in response. This starts with scoping out the purpose of and need for the product, the ways in which it might be used, and by whom, and the constraints and conditions under which it must operate. Based on this understanding, a set of specifications is drawn up to guide product design. A detailed design is then produced, from which a prototype is developed. The prototype is tested, evaluated and refined, before full production and use.

This same process can, and probably should, be followed in indicator development. It is broadly followed here (Figure 3).

3.1 Scoping

The first step in designing indicators is to identify clearly who they are for, and for what purposes they are required. Based on this, the information needs can then be defined.

3.1.1 Users and uses

The potential users of indicators on children's environmental health are clearly many and varied. Directly or indirectly, many different organizations and individuals have responsibilities for children's welfare, and have a need to know about their environment and health. They include international agencies such as WHO, UNEP and UNICEF, national governments and their ministries, regional and local authorities, professional agencies and public institutions, research organizations and, of course, the public themselves.

Each of these may use indicators in very different ways. Some require them to help formulate and assess policy at a relatively broad (e.g. national) level, others to help develop more local strategies. Some may use indicators to monitor the impacts of existing actions, others to identify gaps where new action is required. Some will use indicators to advocate, others to challenge; some to negotiate, others to deny.

One of the factors that distinguishes most clearly different groups of users is their level of responsibility. Whilst users at the international or national level, for example, are mainly concerned with policy formulation and monitoring, those at a local level often use indicators mainly for lobbying purposes. Governments and international agencies are generally interested in the larger picture and broad patterns and trends; for neighbourhoods and local communities what matters are the specifics that directly affect them. Ministries and public authorities require indicators that are quantitative and reproducible; the public and voluntary agencies often demand indicators that are more intuitive and subjective — and thus more in keeping with the qualities that characterize their own lives. Not surprisingly, therefore, these different groups of users often select and design indicators very differently.

Here, our aim is to provide indicators that can help to assess the global and national environmental burden of disease on children both to help prioritize policy, and to monitor and evaluate the effectiveness of national and international initiatives to reduce this global burden of disease. The main users are therefore likely to be the national ministries and agencies responsible for environmental health in the member states. The emphasis is consequently on indicators that may be used at the national or international level, and in an official or semi-official capacity. The intention is that the indicators should be adopted, developed and used by these organizations in the form presented here — and thereby provide a 'standard' indicator set on children's environmental health. Nevertheless, it is evident that different things matter in different places. So individual countries will wish to select and adapt these indicators to meet their own needs.

3.1.2 Issues

Defining the key issues that need to be tackled is never easy. As mentioned, environmental health problems take many forms and can be viewed from different perspectives. Priorities also vary depending on where in the world we are, and on whose behalf we are acting. All of these factors need to be explicitly recognized and sensibly considered before we can realistically define the issues of greatest concern. Because different parties with different interests may be involved, the process of identifying and defining these issues may be as much a matter of politics as it is of science. What is clear is that the choice of issues is crucial. The choices we make and the priorities we set at this stage determine many of the decisions we make later.

Several things can be done to ensure an appropriate selection. As already hinted, one such thing is to involve as many as possible of those who have a need or an entitlement to participate. This means not only the users of the indicators, but also those at whom they are addressed. If the final choice is to be genuine and fair, involvement should also be open and balanced, without undue domination by specific interests. Organizing such participation is rarely easy. Sadly, it still goes against the culture of some organizations, and not everyone who might usefully participate has the commitment, confidence or time to be involved. Achieving representation across diverse, and often traditionally neglected, groups of individuals, is also difficult. There are nonetheless some suitable methods (e.g. Jardine and Hrudey 1998), and many of these have been used in the past, for example to help develop National *Environmental Health Action Plans* (e.g. Victorin et al. 1998). The *HEADLAMP* project likewise showed how participatory approaches can be used at the community level, both to prioritize environmental health issues and to encourage monitoring and surveillance (Corválan et al. 2000).

The second thing that can be done is to make use of the available scientific knowledge and information. This alone does not define environmental health issues, and it certainly cannot prioritize them. On the one hand scientific understanding is itself bounded and sometimes patchy and biased. On the other, setting priorities is a matter of applying value judgements, and though values can never be wholly excluded from science, usually they should at least have been minimized. In any case value judgements are likely to be better if they are informed by the available science. Providing scientific information, and doing so in an understandable form, is therefore an important part of the process of issue selection. (In this sense, there may be a need for what may be termed 'pre-indicators' — preliminary facts and figures, examples, illustrations — that can help those involved make up their minds what the real risks are, and what matters most.)

National and local indicators

The needs for indicators at different levels of application vary greatly. Locally, people tend to be interested most in what directly affects them; these issues may also be seen in very specific and often qualitative ways. At the national level what often matters are the broader patterns and trends, and questions of international consistency and policy compliance become far more important. Objective quantification is therefore crucial.

One example of this difference in perspective is given by the example of urban air pollution. Indicators for use at national level often define this in terms of average annual concentrations of criterion air pollutants: in its *Environmental Indicators* OECD uses the annual concentration of SO_2 and NO_2 as core indicators. Locally, far more prosaic indicators might appear more relevant. *Sustainable Seattle*— one of the first initiatives to develop local environmental indicators — preferred to consider air pollution in terms of 'the number of days on which I can see the mountains!' This may not be easy to measure, and would certainly be difficult to apply at a national scale. But as a basis for local awareness and concern, it certainly speaks far more clearly than objective measures of pollutant concentration.

Attitudes to information

The idea of using indicators to support policy and decision-making is based on a premise: that those concerned actually want to use, and are prepared to use, information to help them make decisions. This is not necessarily true. It is still not unusual to find people who would prefer not to have indicators.

Several different (though usually misguided) factors lie behind this attitude. One is that people may see indicators as a threat to their professional judgement – something that will hamper and bind them rather than help them. Another is that indicators may appear to undermine their status or role – devaluing their specific experience and skill. Some people may mistrust the information that indicators give, believing (perhaps rightly in some cases) that they are no real substitute for insight and understanding. Sometimes, there is a fear that, by making information and understanding more open, indicators will encourage dispute.

These concerns cannot simply be dismissed. They need to be recognized and addressed – not only because they may be genuinely held, but also because indicators will only be effective where they are used as part of a listening, open and information-based approach to decision-making. Sometimes, the most valuable benefit of indicators is that they help to generate this way of thinking and working.

The third thing that can be done is to use explicit criteria to compare and define the issues. These may not always be strictly quantitative: environmental health problems are often too diverse in terms of their effects, and who they touch, to be adequately described simply in terms such as the numbers of dead or average morbidity rate. But there are creative ways of making the necessary comparisons. The use of DALYs is one such method (Kay et al. 2000). Multi-criteria assessment provides another (Jakonowski 1998). Other, less formal, methods have been used to help set priorities in *National Environmental Health Action Plans* (Victorin et al. 1998).

The key issues to be pursued concerning children's environmental health have already been chosen (chapter 2). They were selected primarily by considering the global burden of disease (Figure 1). They comprise the 'big five' amongst contributors to this global burden on children, namely perinatal diseases, respiratory illness, diarrhoeal diseases, insect-borne diseases and physical injuries. This list is, of course, not absolute. Other issues also compete for attention, globally as well as at more local level. The issues highlighted could have been defined in different ways. We could, for example, have included nutritional inadequacies; we might have specified vaccine - preventable diseases. Different issues will therefore need to be identified for other purposes or on other occasions. Because many of the main diseases affecting children share common causes, however, and because the issues defined here are generic, the indicators developed on the basis of this list are likely to have wide relevance. Therefore, while we might wish to amend this list of priorities, many of the key indicators are likely to remain valid and pertinent.

3.1.3 Information needs

Based on these considerations, the key information needs now begin to emerge. In broad terms the need is for information that focuses on these 'big five' environmental health issues, at the national scale, to help guide, compare and assess policy actions and impacts.

To translate these general needs into specific information requirements, however, we need to go much further. We need to be able to identify how these various risks to children's health are actually played out in the real world — what are their causes, how they operate, and what sort of information we therefore require. This is no easy task, for it is evident that associations between environment and health are complex and multi-facetted. So-called environmental causes are not always either immediate or direct; nor do they act in isolation. Many-to-many relationships between environment and health abound. Most health issues also have roots that reach far beyond the physical environment, deep into underlying social circumstances, economic actions and policy.

Furthermore, the ability of children (and those on whom they depend) to cope with these risks, and their susceptibility to them, are to a large extent socially and economically determined. Environmental health issues are thus not merely issues of environment and health, but also of the social, economic and policy factors that shape and drive them. Moreover, research on the associations between environment and health has been limited —all the more so in the case of children. Consequently, we often do not have reliable dose-response relationships on which to base judgements of risk, nor even a clear understanding of the environmental aetiology of many diseases. Two crucial problems therefore commonly arise. First, when we define health outcomes, we cannot definitively relate these to specific environmental causes or exposures, nor in many cases assess an 'environmentally attributable' risk. Second, when we consider environmental conditions or exposures, we cannot reliably extrapolate from these to deduce true measures of health effect.

All this makes identifying information needs difficult. One way of making progress, however, is to construct a matrix that relates each of the major burdens of disease to its main environmental causes (Figure 4). This is helpful, not only because it begins to show the types of information we need, but also because it highlights the ways in which these different issues overlap and interact. None represents a unique area of environmental health concern. All share causes, mechanisms and pathways, all interact. For this reason, too, many might be influenced by common policy actions. For the same reason, many imply shared information needs.

It is clear that the health outcomes and hazards contained in Figure 4 can be endlessly debated. The rationale for the choice of health outcomes has been given earlier (see chapter 2.1). The hazards associated with each of these have been defined to be as comprehensive as possible. But some issues may seem to be lacking. Malnutrition, for example, has been omitted as a health outcome because it is expressed through many different health effects; it is represented, however, through the hazard of food safety and security of supply. Climate change is omitted, also, because its impacts on health are translated through several of the other hazards included in Figure 4: notably through its effect on food security, water quality and supply, natural hazards (e.g. floods) and disease carrying vectors. As this implies, when we attempt to define issues and identify the links between cause and effect, we must try to avoid duplication, for this can greatly bias our choice of indicators. This is not always easy, however, for environment and health are never clearly compartmentalized, and the boxes we choose to define things are rarely mutually exclusive.

3.2 Selection

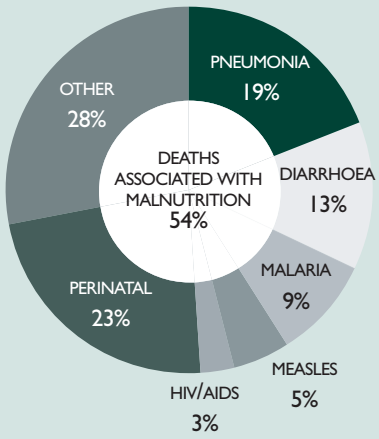
Scoping of the information requirements of the key users provides a basis on which to select the indicators that best meet these needs. Selection, however, cannot be a purely intuitive or random process. Each of the issues on which users need information may be conceptualized in different ways: the indicators we design are likely to vary accordingly. Defining the best indicators (or even those that are merely satisfactory) also implies that we understand how to judge their effectiveness. Before we select indicators, therefore, we need to understand both the conceptual framework in which we are working, and the key criteria that the indicators must satisfy.

3.2.1 Conceptual framework

Given the complexity of environmental health issues, it is clearly useful to have some form of framework to help build and structure indicators. This will not only help ensure the selection of a balanced and relevant range of indicators, but also help to recognize and understand the complicated links between them, and to interpret properly cause and effect (links and associations that are only hinted at in Figure 4).

Malnutrition – the missing issue

Inadequate nutritrion is one of the world's great killers. Globally, it is estimated to contribute to about 54% of deaths among children under 5 years of age, as the figure below indicates.



The omission of malnutrition (or underweight) from the 'big five' environmental health issues may therefore seem surprising, and certainly requires justification.

The justification is, in fact, evident in the diagram above. The issues selected here are all defined in terms of the health outcome, rather than the source of exposure or cause. As the diagram above indicates, however, malnutrition is a cause of disease and death, rather than an outcome in its own right. It is therefore taken into account not as a separate issue, but as one of the risk factors implicated in almost all of these issues.

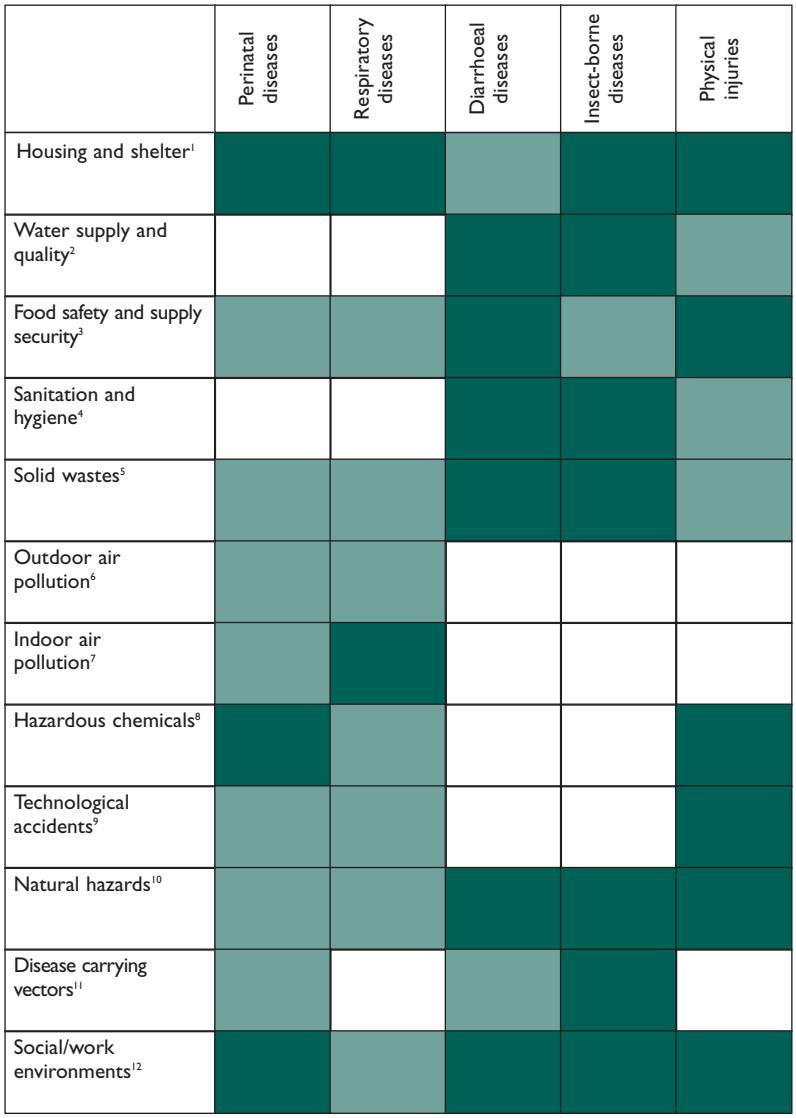
This approach is not mere pedantry. It has two important implications. On the one hand, it helps to avoid 'double counting' of health effects. On the other, it helps to emphasize the shared causes of many health outcomes.

Figure 4. Environment-health matrix for major health risks to children

Dark shaded cells represent environmental factors that are major contributors to that specific health outcome; lighter shaded cells represent environmental factors that are significant, but not major, contributors.

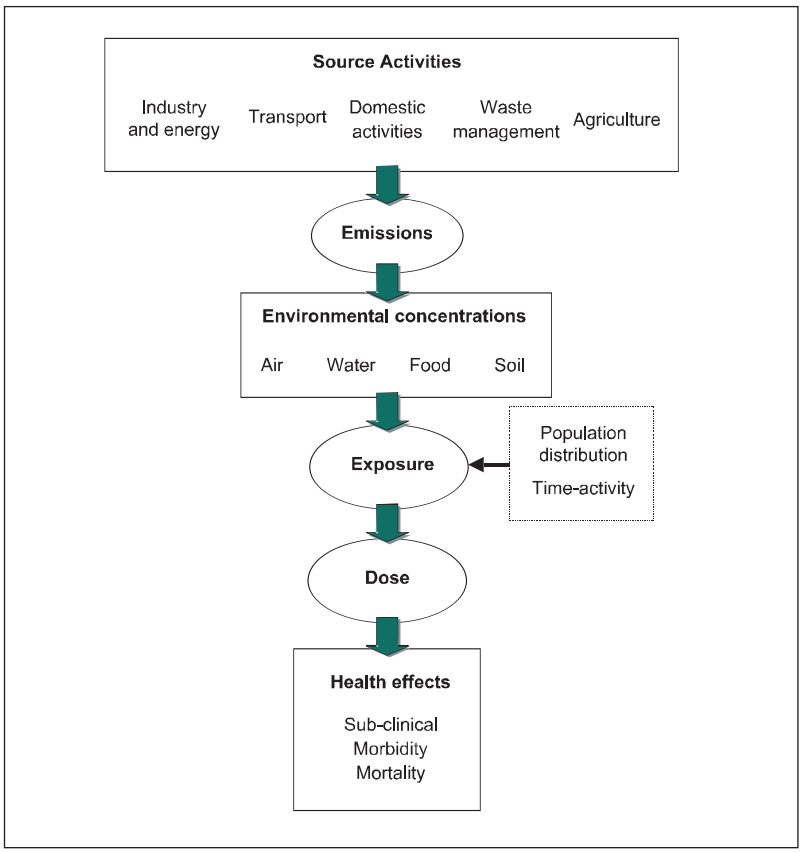
1. All aspects of housing availability and quality, overcrowding, dangerous or unsafe housing, dampness and poor ventilation.
2. Access to safe and sufficient water for drinking and personal hygiene, and drinking water quality.
3. Food contamination and hygiene (at all stages in the supply chain and in the home), food additives, nutritional quality of food, and security of food supply.
4. Excreta disposal facilities and facilities for personal hygiene in the home.
5. Waste disposal facilities in the home, waste collection services, waste treatment and disposal.
6. All forms of pollution in the ambient air.
7. Indoor sources of air pollution (e.g. heating and cooking, furnishings, environmental tobacco smoke) and outdoor pollutants that enter the home.
8. All forms of household, industrial and agricultural hazardous chemicals.
9. Road traffic accidents, falls, burns, industrial fires, explosions, war etc.
10. Earthquakes, volcanoes, floods, drought, storms, heat stress, ultraviolet radiation, cold, slope failures etc.
11. All insect, worm, snail and other biological vectors.
12. Recreation, transport, workplace.

Source: adapted from WHO 2002



In recent years, many different frameworks for indicator development have been devised. Underlying many of these is the concept of the environment-health chain (Figure 5). According to this, hazards such as pollutants originate in human activities such as industry, transport or waste management. Released into the environment, these pollutants are carried via different processes through different environmental media (e.g. the soil, water, air, food). Exposure occurs when humans come into contact with these pollutants in the environment. Depending on the degree of exposure and the inherent susceptibility of those concerned, adverse health effects may then occur.

This model of environment-health links is relatively simple and highly visual. It emphasizes the conditional nature of environmental impacts on health. Adverse effects only arise if there is a hazard with the potential to do harm, and if people are exposed to that hazard. It also highlights the importance of understanding the (often remote) causes behind health effects if we are to tackle them effectively. Indeed, this model of environment-health relationships has in the past been translated into a formal framework for policy and indicator development — the so-called DPSEEA (pronounced 'deepsea') framework (Figure 6).



The DPSEEA framework has been widely used as a way of both selecting and structuring environmental health indicators, and has already proved its usefulness. One of its main strengths is that it clearly shows the many different points at which we can intervene within the environment-health chain — not just by treating the disease but also by reducing exposures (e.g. by educating people in risk avoidance), by mitigating impacts on the environment, and, far upstream, by changing our industrial and other activities in order to prevent the release of pollutants in the first place. Equally, the framework helps to illustrate the human source of adverse effects of the environment on health. The environment acts as the pathway for exposure, but the hazards themselves often originate far more remotely in — or as a by-product of — human activities. And many of these activities are themselves products of policy. Policy thus acts as both a driver for, and a potential response to, human suffering.

That said, the DPSEEA model — like all models — is a simplification of reality, and as such misses things that might be important. If read too literally, it can mislead us quite seriously. Its emphasis on anthropogenic causes, for example, means that it is most relevant for hazards such as pollution and works less effectively for natural hazards, such as earthquakes or floods (though these, too, may have human triggers). More crucially, in stressing the linear links between environment and health, it tends to neglect the actual complexity of these associations — in particular, the many-to-many links that are often involved in the real world. The reality, of course, is that individual hazards often lead to a wide range of adverse health effects, while single health outcomes may derive from many different exposures and underlying causes. Ignoring this complexity can be dangerous, for it may encourage us to seek simple, singular solutions to complex, multifactorial problems.

Figure 5. The environment-health chain

Why conceptual frameworks matter

Issues relating to children's environmental health can be defined and selected in many different ways: for example, in terms of the underlying activities and factors that we believe give rise to health risks, in terms of the agents that actually generate the risks, or in relation to the health outcomes.

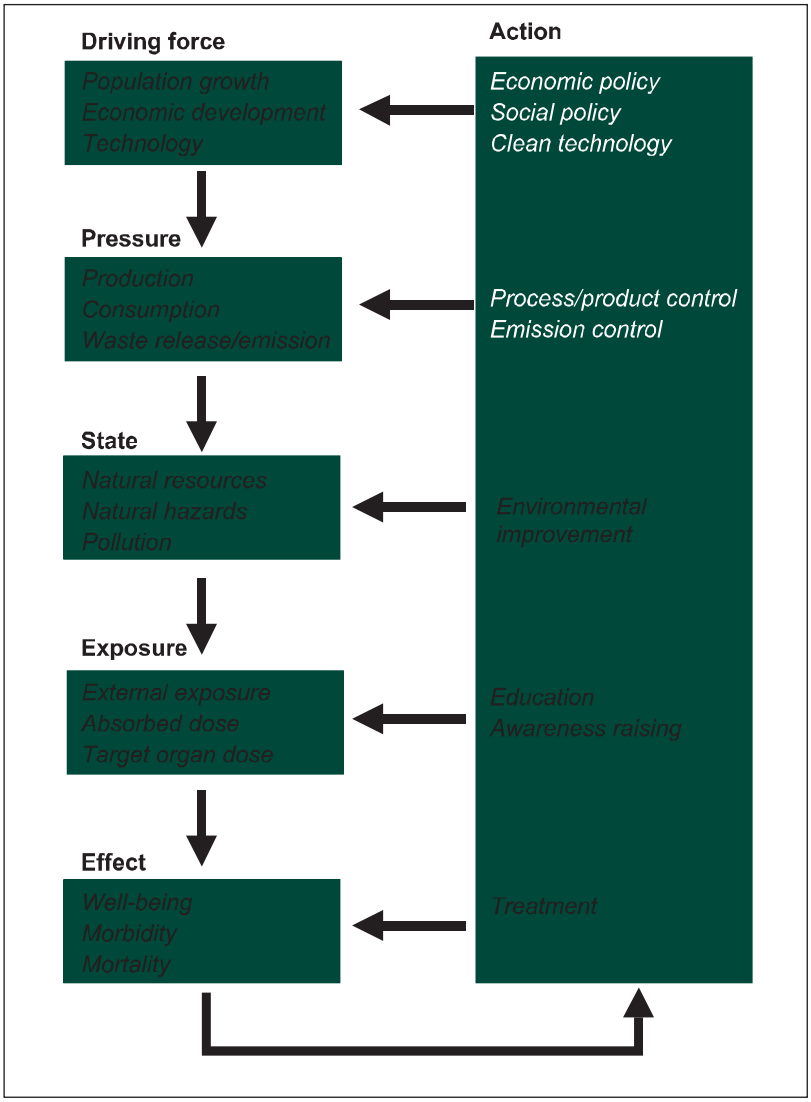
Which we choose can matter. Taking either a source-based or agent-based approach, for example, might help us to act more preventively, by focusing on the causes of ill health, but at the cost of missing signs of health problems for which the causes are unknown. Taking a health-based approach means that we define priorities in terms of disease outcomes and then seek their causes in the environment. But this means that we may not see the problems before they occur.

If we are to avoid the biases inherent in any one of these approaches, we need to make the links between source, agent and effect as clear as possible. Then, whatever approach we choose will still give us a clear and balanced picture. Here we take a health-based approach. But we could equally well have taken a source- or agent-based approach. For by using an explicit conceptual model of how each health risk arises, we ensure that neither causes nor agents are ignored.

Figure 6. The DPSEEA framework

The model describes six components of the environment-health chain:

- Driving forces — that act as root causes for, and influences upon, the processes of concern
- Pressures on the environment — that arise as a result of these root causes
- State — changes to the environment as a consequence of these pressures
- Exposures — that take place when humans are exposed to these changed environmental conditions
- Effects — adverse impacts on health due to these exposures
- Actions — policy and other interventions, aimed at reducing or avoiding these adverse health effects



Other ways are thus needed to represent the links between environment and health and many other models and frameworks can be suggested. Figure 7 shows one — the MEME model. This is both a simplification and an extension of the DPSEEA model. Unlike the DPSEEA framework, it does not try to separate more proximal causes of disease (exposures) from more distal causes (the state and pressure components): instead, all these are combined under the general heading of exposures. It recognizes, however, that exposures may be measured either more or less directly — for example, by indicators of exposures per se, environmental concentrations, or source activity. It also shows how exposures occur in different settings — in the case of children, including the home, the community and the wider, ambient environment (see also Figure 5). In the same way, it recognizes that health effects may be expressed in different ways (e.g. as morbidity or mortality). In addition, it recognizes that both exposures and health outcomes may be affected by more remote, contextual factors, such as social conditions, demographics and economic development, that influence the susceptibility of the population to environmental health effects. As with the DPSEEA model, actions are seen to be taken either to remedy disease or, preventatively, to avoid it by reducing exposures in the environment. In the longer term, actions may also be targeted at the underlying factors — for example, by trying to alleviate poverty or enhance development.

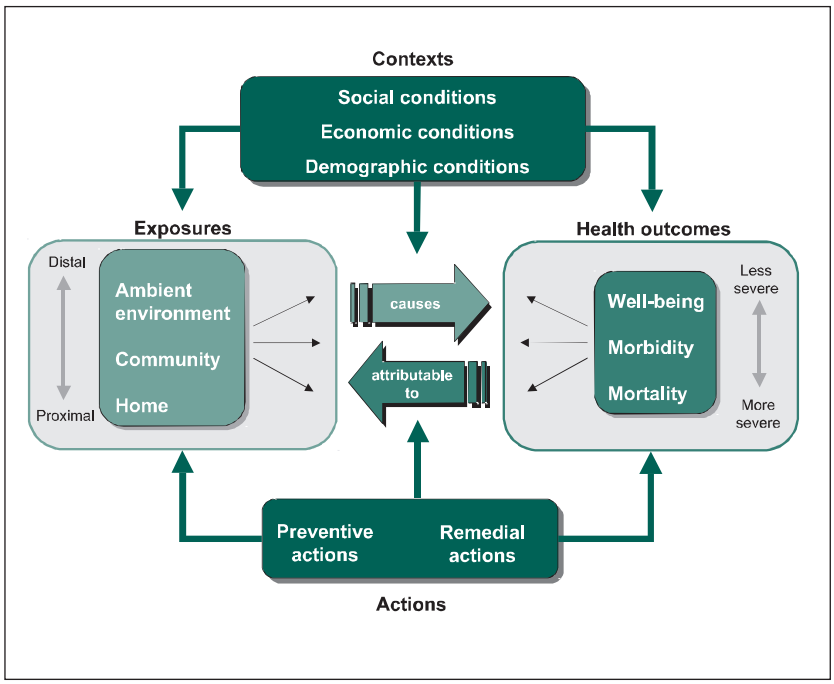


Figure 7. The MEME model

The Multiple Exposure-Multiple Effect (MEME) model emphasizes the many-to-many links between environment and health. Exposures, in different environmental settings (on the left) lead to many different health effects (on the right). Individual health effects (on the right) can be traced back to many different exposures (on the left). Both exposures and health outcomes — as well as the associations between them — are affected by contextual conditions, such as social, economic or demographic factors. Actions can be targeted at either exposures or health outcomes (and in the longer term, also, at the underlying contexts).

As the name implies, the MEME model also emphasizes the many-to-many relationships between environment and health. This is an important aspect of the model, for it implies that neither exposure nor health indicators can usually be interpreted in terms of simple, direct relationships. Most are divergent: individual exposures can lead to many different health outcomes; specific health outcomes can be attributed to many different exposures, in different settings.

In truth, none of these models is likely to be all-embracing and perfect. Models are not meant to be: they are simplified approximations of reality, that serve as tools for specific needs. There are, however, important advantages in using such models in selecting issues and in developing indicators. One is that they help to make explicit our underlying concept of the way the world works. As such, they may reveal our unstated assumptions and biases. Another is that they help us to be more systematic in defining the issues that confront us and in selecting indicators to represent them. Thirdly, they help to demonstrate the logic of what we do — showing the links, for example, between the various indicators we develop. Finally, they provide us with a tool for analysis and interpretation: for example, to start asking how the health of children might be affected if one of our exposure indicators shows a change; or to explain trends in health in terms of the changes we see in indicators from further up the environment-health chain.

Nevertheless, more detailed and more flexible ways of describing issues of concern, and thereby focusing on key indicators, are often required. One way of doing this is through the use of systems models. These are based on seeing the world as a set of components linked together by flows of energy, matter or information (in other words, by causal links). In this way, the systems that define each issue can be represented as a network of boxes (depicting the key components) and arrows (depicting the flows). This is the approach we will use here.

Models of environmental health issues can become extremely complex: indeed, one of the dangers of modelling is that we try to be too clever and include everything we know about the world. The result tends to be confusion rather than clarity. In order

Many-to-many associations between environment and health

Almost all health effects, and almost all exposures, demonstrate the many-to-many associations that characterize environmental health. Acute respiratory illnesses, for instance, may occur as a result of exposures to a wide range of pollutants in the ambient atmosphere, as well as indoor air pollution, dust mite, pollen, moulds and pets in the home, and allergens in food. Equally, exposures to atmospheric pollution have been associated with a range of respiratory illnesses, as well as circulatory illnesses and cancers.

to deal with this complexity, however, it may be useful to order the issues quite formally. We might use the DPSEEA framework for this purpose: components can then be grouped according to whether they represent driving forces, pressures, state, exposures or actions. Here (chapter 3.3) we use the MEME framework, but, as we have seen, it is relatively easy to switch between the two. Models and frameworks are merely tools, not strait-jackets, and we should be prepared to adapt them, or exchange one for the other, according to need.

3.2.2 *Criteria*

Models help us to depict the issues with which we are concerned, but they do not immediately provide us with a set of indicators. To develop these, we need to analyze the models and identify within them the key elements for which indicators are needed. We then need to specify exactly what indicators we will devise, and how they will be constructed. In the process we have many different choices to make, not only about where to site our indicators, but also how to define them, how they should be measured, and what purpose they might fulfill. If we are to make these choices rationally, some guidelines or criteria may be of considerable help.

Many previous attempts have in fact been made to derive criteria for indicators, and several different sets of criteria have been developed and published (e.g. Briggs and Wills 1998, Corvalán et al. 1996, 2000). Most agree on two general criteria — that indicators should be scientifically valid or credible and that they should have clear relevance and utility. In many cases, issues of practicability (e.g. cost, data availability) are also noted.

Each of these general criteria can be specified in a variety of ways. The weights given to the specific criteria may also vary from case to case. Much depends upon the level of responsibility of the users and the intended scale of application (e.g. whether international, national, regional or local). Often, too, the criteria appear to be to some extent contradictory. The need to produce indicators that are readily understood by, and resonate with, the public, for example, may be in conflict with the need for scientific validity. Equally, the need for accuracy and scientific credibility may create tensions when set against the need for timeliness, ease of construction (feasibility) and low cost. These conflicts and contradictions are to be expected. Indicators are tools, and all tools have to fit the purpose for which they are intended. There are thus no absolutes. What makes an indicator good for one purpose in the hands of one user may not be appropriate in the hands of another. The criteria, like the indicators themselves, are dependent on the situation in which they are used. In the end, however, perhaps only one criterion matters: that they do their job. The proof, as ever, is in the eating.

In the case of national indicators, like those being developed here, six main ingredients make the meal. The first is *scientific credibility*. As already noted, indicators are a way of describing something — an impact on health, a risk, a source of exposure — that is not otherwise easily assessed. How well any indicator does this depends on how well it actually relates to the phenomenon concerned: in other words, how well the indicator indicates. Whilst this might seem such an obvious requirement of any indicator that it need not even deserve mention, in reality it is often one of the most difficult criteria to achieve. Many of the indicators developed in the past can be criticized in this respect.

Criteria for environmental health indicators

Scientific validity:

- credible — *i.e. based on a known linkage between environment and health*
- sensitive *to changes in the conditions of interest*
- consistent and comparable *over space and time*
- robust — *i.e. unaffected by minor changes in methodology, scale or data*
- representative *of the conditions and area of concern*
- accurate — *i.e. based on reliable data*
- scalable — *i.e. capable of being used at different scales*

Utility and practicability

- relevant *to an issue of policy or practical concern*
- actionable — *i.e. related to a condition which is amenable to influence or control*
- understandable *by and acceptable to those at whom it is addressed*
- timely — *i.e. up-to-date*
- specific — *i.e. targeted at an explicit phenomenon or issue*
- measurable — *i.e. based on available data and manageable methods*
- cost-effective — *i.e. capable of being constructed and used at acceptable cost*

The problem, as we have seen, is that most aspects of environmental health are multi-dimensional. Simple one-to-one relationships rarely exist; complex, interlinked associations predominate. As a result, it is often difficult to find indicators that provide a singular and direct measure of a health outcome or exposure. Many are confounded, many uncertain. In these situations, interpretation is extremely difficult. Apparent differences or changes in the indicator might mean one thing or the other, or nothing at all; we cannot tell which. The indicator fails to indicate.

There are two main ways of avoiding this difficulty. One — and usually the best — is to be rigorous in defining the indicator in the first place. We should eschew indicators that are inherently uncertain or ambiguous. The other is to use indicators not in isolation, but in combination — as mutually supportive tools. What we cannot deduce with any certainty from a single indicator can often be much more clearly seen if we read the signals of several together. Interpreting a fall in the rate of injuries to children in road accidents might be difficult, for example. Is it due to reduced levels of road traffic? Is it a result of improved road safety? Is it because children no longer dare walk or play in the streets, and thus are missing out on exercise? Or is it an artefact of some change in the classification or reporting of accidents and injuries? If we take the indicator on its own, we can only guess. But if we triangulate — if we compare trends against other indicators — the picture may become clearer.

Comparability and consistency are also important in relation to national indicators. Comparability over space is crucial if we are to draw meaningful comparisons or contrasts either between different regions within a country, or between different countries. Consistency over time is essential if we are to observe and understand trends. Both require not only that the indicator used is constant in terms of its definition, but also that the methods and data used to construct it are consistent and standardized.

Achieving such consistency is not always easy. One problem is that, internationally, different interests and different standards often prevail. Many countries also have well-established, but different, systems for monitoring and survey: understandably, they are reluctant to compromise these for the sake of international conformity. Indeed, if they do so, they are likely to jeopardize the consistency and continuity of their own time-series data.

To make matters worse, monitoring and survey technologies and practices also change over time. Organizations responsible for monitoring are thus faced with a dilemma. Do they adopt new technologies as they become available, in order to improve the quality of their monitoring and to maintain consistency with their neighbours? Or do they retain old, and increasingly outdated methods in order to keep faith with historic data? One area in which this has been a major issue is remote sensing. As the number and range of Earth observing (EO) satellites has increased, and as the capability of the sensors they carry has improved, remote sensing has become a progressively more important source of environmental data. But as these same advances have occurred, consistency of the time series data has been ever more seriously compromised. Similar problems occur with health data. Few countries, at some time or other, have not made improvements to their systems for reporting and coding or morbidity and mortality. Whenever they do so, an apparent jump occurs in health trends — a product not of any real change in health status, but of surveillance methods. Unless these artefacts in the data are recognized and understood, they can cause major misinterpretations of the message that the indicators convey.

Scientific credibility

A primary requirement is that an indicator must be based on a known and interpretable linkage with the phenomenon or condition of concern. Achieving this in the case of environmental health indicators is surprisingly difficult. Consider, for example, the following two widely used indicators:

- *percentage of household waste recycled*
- *SO_2 emissions per head of population*

Though each of these is in some way associated with environmental conditions and quality of life, neither has a clear or explicit link to human health. Because of the way they are defined, they are also difficult to interpret. Recycling of waste, for example, may help to reduce the need for landfill or incineration, and help to avoid waste dumping, but, unless properly managed, it may increase waste handling. Moreover, high percentages of waste recycling may still leave large volumes to be disposed of in other ways, if total waste generation is excessive. Similarly, high per capita SO_2 emissions might not pose any threat to health if the population is very sparse (in which case the total quantity of emissions will still be small) or if emissions are mainly from tall stacks and are hence widely dispersed.

How consistent should indicators be?

Consistency and comparability are clearly essential if we wish to use indicators to make comparisons either over time or geographically. But forcing consistency on indicators can be detrimental. Different issues may be of concern, for example, in different countries; often, also, common problems may be expressed in different ways. Making every country use the same indicators may therefore distort the picture and hide important problems or disparities. Over time, also, problems and interests change. If these are to be properly represented by the indicators used for policy-making, these too need to change. Both consistency and continuity may therefore need to be sacrificed if indicators are to remain relevant.

The representativeness of borrowed data

Most indicators rely on borrowed data — that is on information collected for other purposes. How representative the indicators are thus depends on how the original monitoring or data collection was designed. Unfortunately, much monitoring is carried out for purposes that have nothing directly to do with environmental health. Much is for compliance purposes: for example, to check that international obligations are being met, or to ensure that national legislation is being enforced. Monitoring networks in these cases are often biased towards specific types of environment: air quality monitoring, for example, is often focused at known pollution hotspots. Extrapolating data from these networks to the wider area or population (e.g. to derive measures of the mean annual pollutant concentration, or population-weighted exposure) can be highly misleading. We therefore need to recognize (and clearly state) the biases and limitations of our borrowed data – and interpret the indicators accordingly.

In the same way, we need to be concerned with how *representative* our environmental health indicators are. The reason for this concern is all too evident: if indicators are to be used to inform decisions, the information they provide should be unbiased. In practice, this is often difficult to achieve. As we have seen, matters of environmental health are extremely complex. Conditions often vary over short distances, and even within small population groups. Survey and monitoring are, however, often expensive. Many indicators thus rely on sample data — for example, on environmental monitoring carried out at a relatively small number of sites, or on household surveys covering a small percentage of homes. In both cases, sampling poses major challenges. In complex, highly clustered or stratified populations, random sampling cannot provide reliable estimates, unless relatively large samples are taken. Careful stratification of the sample is needed. Yet this is difficult unless the structure of the variation in the phenomenon of interest is known — that is, unless we understand how it varies between different areas or population groups. Large uncertainties in our estimates therefore arise, especially when they are applied to small areas or sub-populations. This problem becomes all the worse if the condition of interest is rare. Interpreting patterns or trends shown by an indicator in these instances is highly problematic — or simply foolhardy.

Similar problems occur in relation to time. Environment and health rarely show simple and smooth temporal trends. More commonly, variations over time are complex and jerky: periods of little or slow change are punctuated by sudden and abrupt dips or jumps. Rarely, also, are such events wholly regular and readily predictable, even when driven by cyclical processes such as the seasons, sunspots or economics. Superimposed on the signal of all these real changes is the random noise created by measurement or sampling error. Detecting change in time-series data against this background of uncertainty is therefore often difficult. Where indicators can be derived from continuous measurements, such as air quality monitoring or routine health reporting, there is a good chance of identifying real changes in conditions. Where the indicators are based on periodic surveys (such as household questionnaires or environmental surveys) the problem is much greater. For the indicator then becomes a palimpsest: a series of fragments plucked from a huge tome of information. Deciphering the story — reconstructing the pattern — on the basis of such partial evidence may then be all but impossible.

Timeliness of indicators is also important for other reasons. If they are to serve to influence our actions effectively — to help us intervene in a way that prevents suffering, repairs damage, or mitigates misery rapidly — speed is of the essence. At best, we need warning; at worst, we need to know quickly after the event that things have already begun to go wrong. Good indicators are therefore both up-to-date and available without undue delay.

This presents some problems in the area of environment and health, for many of the data sources on which we rely do not operate on these sorts of time scale. Environmental and health surveys, for example, may happen only sporadically, or at intervals of several years — so we may not get warning of events in the interim. Processes of data gathering (e.g. from the many different organizations responsible for health monitoring) may also be lengthy, and much effort may need to go into data checking and verification. Lags of two or three years are therefore not uncommon before information is available and indicators can be updated. This problem inevitably means that we are often forced to act after the event, especially if we rely on health indicators alone. It can also act to weaken environmental health interests when set against those of others — such as economics — that are supported by more timely information. It becomes all too easy in these circumstances to dismiss environmental health as 'no longer relevant' or 'out of date'.

There are no easy solutions to the question of timeliness. Cost tends to prevent us from carrying out frequent surveys or continuous monitoring. We cannot afford to ignore possible errors in the data, so data cleaning and validation are vital. As a result, delay is something we have to learn to live with. There are, however, some things that we can do. One is to use other measures to give us earlier warning — in particular, to focus on exposures and the causes of exposure, rather than health per se , as a source of indicators. For this reason, indicators from higher up the environment-health chain (exposures, environmental concentrations, source activities) are often more useful than measures of health effect. Another is to use modelling as a way of predicting what might happen, given what we know of current conditions and recent trends. Such predictions may not be wholly accurate, but they can undoubtedly help us to be prepared. And in health, perhaps even more than in relation to the environment, preparedness and precaution are paramount.

As all this suggests, *measurability* is the fifth ingredient of good indicators. Indicators, like all forms of information, are only as good as the data on which they are based. If we cannot obtain the necessary data, our indicator remains empty and meaningless. This is not to say that indicators have to be built on hard data, derived from direct measurements, nor that perception and opinions do not matter. Modelling — as noted above — can be an equally valid basis for indicators. So can softer forms of data, such as those obtained from attitudinal surveys. People's concerns, after all, are often what shape their actions; and anxieties directly impact on quality of life. In many cases, also, people are remarkably perceptive, and detect problems and changes long before more formal monitoring systems. In some circumstances, we have admittedly little choice, for other forms of data may be unavailable. We should certainly not dismiss such data, therefore, nor be afraid to use them in developing indicators.

Measurability, however, does not stand alone. Given enough resources, we could probably find ways of measuring most things. In the real world, the main consideration is cost, while the second is probably the need for timeliness. For both these reasons, our choices are far more circumscribed. Indicators thus tend to rely on routine data where they can; purpose-designed monitoring or survey campaigns are only carried out as a last resort. It is the limited availability of routine data that consequently represents the real constraint. It is not that we cannot measure what we need to build our indicators, but that it is not affordable to do so. *Cost-effectiveness* is thus measurability's twin. Together, they act to define the practicability of many indicators; and they sound the death knell for many a potentially clever idea.

In the case of indicators on children's environmental health, meeting these various criteria poses particular problems. This is not only because the indicators themselves are demanding, and in some cases incompatible. It is also because routine, representative, accurate and affordable data on children are often scarce or lacking.

There are many reasons for this. One is perhaps the children's inherent lack of voice: because of their own immaturity, their financial inconsequence, their exclusion from — or inability to exploit — the channels of influence that exist, their problems are likely to be less often seen or heard. And when they are, this is only through the words of others. A second, and not unrelated, cause is the bias inherent in where and how we carry out our environmental and health monitoring. For example, we measure the ambient environment; we regulate the workplace; we record adult perceptions and activities. But all these tend to represent only poorly the environments that children occupy, what they experience, and the threats and hazards they face. Even the level at which we measure air pollution, for example, is traditionally that of an adult's breathing height.

Perceptions and opinions as data

People's perceptions are a rich source of information that should not be neglected. Perceptions of personal health and well-being and of the state of the environment can tell us a great deal about what matters to people and about the conditions in which they live. Perceptions are also a source of data that can be relatively easily tapped — for example via opinion surveys and questionnaires. They can therefore help to fill in gaps in data that cannot be obtained by more traditional means.

But collecting and using this type of information has another important benefit. It provides a means of involving the public directly in the process of indicator development. This can help to make the indicators seem far more meaningful and relevant, and encourage their acceptance by the public.

Children as denominators

Children are not little adults. If we are to make indicators specific to children, therefore, we need to define them directly in terms of children themselves. One obvious way of doing this is to use children — rather than the population at large — as the denominator. When developing an indicator of risks from indoor air pollution, for example, we should design it in terms of the number of children exposed.

Yet defining children as denominators is rarely sufficient. For many environments pose different — and greater — risks for children, than they do for adults.

Drowning, for example, is a common cause of mortality for children, because water sources (used for drinking, bathing, washing) are hazards; for adults, these activities tend to be far less hazardous. Similarly, indoor air pollution poses far greater risks to young children, who spend large proportions of their time at home, than it does to adults (especially males) who are away from the home much more. We therefore need to take account of the differential risks faced by children in many environments, compared to adults. We also need to target indicators at the specific age groups of children who are most at risk.

Key indicators of perinatal diseases

Contexts

Children aged 0–14 years living in poverty

Exposures

Famine risk

People living in informal settlements

Women of childbearing age who are malnourished

Women of childbearing age working in unregulated workplaces

Births to mothers living in unsafe or hazardous housing

Health outcomes

Perinatal mortality rate

Intrauterine growth retardation in newborn children

Congenital malformations requiring surgical correction in children under 1 year of age

Actions

Women of childbearing age within one hour's travel of specialist maternity and perinatal care

Attributable change in number of households lacking basic services

Prevalence of stunting in children aged 0–4 years

Devising indicators that are specific to children — that focus on the things that matter to them, and describe them from the perspective of a child — is often extremely difficult. It is not really adequate simply to see children as alternative denominators: we should not expect to translate indicators for the general population to children merely by substituting 'total population' with 'total numbers of children' in the algorithms we use. Lack of child-specific data, however, unfortunately means that we often have little choice.

3.3 An indicator list

Armed with an understanding of information needs, a clear conceptual framework, and rigorous criteria for indicator selection, we can now make our choice. To help us do so, we can model each of the key environmental health issues in turn and identify the components and links that need to be described. At this stage, the list we draw up is only provisional, since we may not be sure which of the indicators can, in practice, be constructed with the knowledge and data available, and which will work. Later, we might revisit the list to see whether there are important gaps or redundancies. In looking for gaps, we need to appreciate especially that the boundaries we place around each of these issues are somewhat arbitrary. In reality, most, if not all of them, interact, and we need to ensure not to neglect these interactions. By the same token, we may find that some of the indicators are near duplicates. In this case we might be able to save effort and time by merging some of them. The indicators therefore need to be looked at holistically and in context, rather than as isolated entities.

3.3.1 Perinatal diseases

Perhaps more than at any other time in their lives, children are at risk during the period immediately prior to, and soon after, birth. Perinatal diseases consequently represent one of the major causes of loss of life and illness amongst children world-wide.

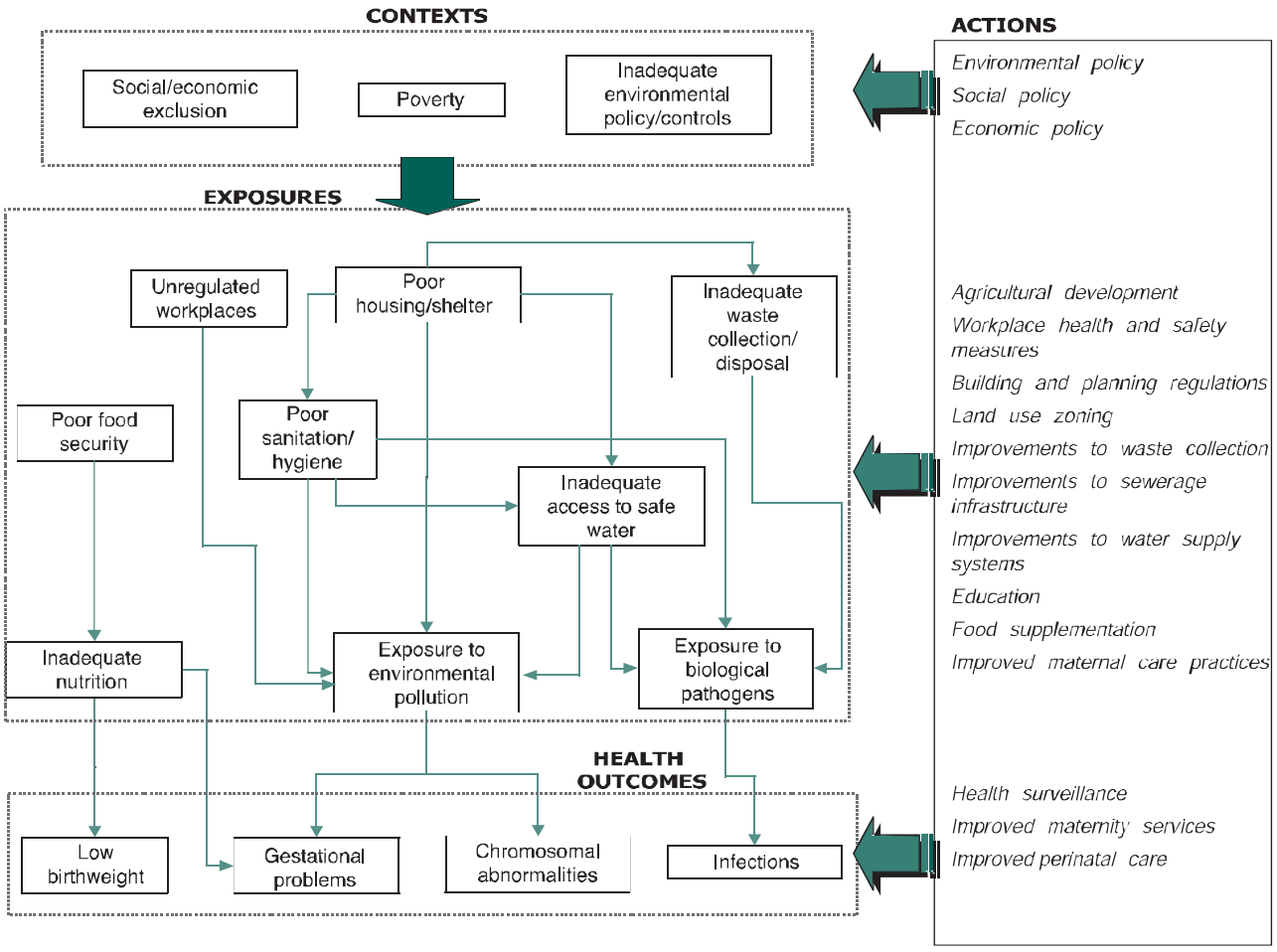
Definitions of perinatal diseases vary from country to country. WHO, however, defines them as those that occur between the 22nd week of gestation and the end of the first week after birth. They take many different forms. Globally, the main contributors to perinatal ill-health or death are:

- Gestational problems (e.g. prematurity, post-prematurity and stillbirths).
- Intrauterine growth retardation.
- Neonatal infections (e.g. sepsis, pneumonia).
- Fetal blood loss.
- Physical injuries before or during birth (e.g. asphyxia or birth trauma).
- Chromosomal conditions.

In terms of health effect, a general indicator on the extent of these diseases is clearly useful. For this purpose we might use a measure such as the perinatal mortality rate. For more specific applications, however, it is useful to define other health effect indicators.

- *Intrauterine growth retardation in newborn children* identifies those most at risk.
- The number of *children born with congenital malformations requiring surgical correction* is also a useful indicator of more extreme birth defects, including problems such as neural tube defects and gastroschisis, which are on the increase in several countries (Kold, Jensen 2001).

Figure 8. Perinatal diseases



As Figure 8 shows, various environmental factors contribute to these health effects. The main concerns focus on maternal exposures, care practices and nutrition during the prenatal period, and conditions in the home in the days immediately following childbirth. Several key indicators of these exposures can be proposed.

- The number of *women of childbearing age who are malnourished* is a general indicator of the risk of inadequate nutrition, and consequent gestational problems, during pregnancy.
- The number of *mothers of childbearing age working in unregulated workplaces* gives an alternative indication of the potential for maternal exposure to teratogens and other hazards for the unborn child.
- The number of *births to mothers living in unsafe, unhealthy or hazardous housing* is an indicator of general risks of infection or poor birth environments in the home.

Additional indicators that might be developed in specific cases, include:

- the number of *hospital admissions for maternal intrauterine or rubella infection,* which provides a measure of maternal infections likely to cause birth defects or gestational problems;

The lasting legacy of childhood disease

Low birthweight, one of the most common and pervasive of adverse health effects, has more than a temporary effect. It is implicated in a wide variety of diseases in later life, including respiratory and cardiovascular diseases. It is also associated with various social disadvantages such as reduced employment opportunity and increased risk of violence.

Designing good action indicators

Of all the indicators we have to design, those relating to actions are perhaps the most problematic. The difficulty arises to a large extent from the intimate relationship between action and effect. Simply knowing that action has been taken is clearly not enough; we need to know how well it has been implemented. For example, an indicator such as the *existence of an energy policy* tells us little, since we do not know how extensive it is, nor how effective it has been. On the other hand, if we focus only on the effect of interventions, we end up using the same indicators that we used to define the problem in the first place (e.g. *the number of households relying on biomass fuels*)!

There are two solutions to this dilemma. One is to develop action indicators that describe (and as far as possible quantify) the degree of implementation. This can be done, for example, by scoring different measures in terms of their rigour and extent. A second approach is to use indicators that describe the attributable change in the conditions at which the actions are targeted, or of the extent to which the policy targets are being met. Both these approaches are used here.

- the number of *poisonings of women of childbearing age by chemicals in the workplace or home,* which can act as an indicator of the risks of acute maternal exposures to teratogens and other hazards for the unborn child.

More remote risk factors also exist, for which indicators can likewise be developed, either as proxies for exposures (where these cannot be measured) or as indicators in their own right.

- *Famine risk* provides a general measure of food security and the likelihood of malnutrition — and thus of birth problems — in the general population.
- The number of *people living in informal settlements* gives an indication of general birth-related and perinatal risks in the home environment.
- The number of *children aged 0–14 years living in poverty* acts as a general descriptor of socio-economic deprivation — one of the strongest (though least specific) risk factors for perinatal diseases.

Action to prevent or reduce the risks of perinatal diseases can be targeted at any one of these factors. Key indicators thus include:

- the number of *women of childbearing age within one hour's travel of specialist maternity and perinatal care*, which gives an indication of the effectiveness and penetration of health care facilities;
- the *attributable change in the number of households lacking basic attributable services*, which provides an indicator of the degree to which essential needs, such as sanitation, hygiene, safe water and waste collection are met;
- the *prevalence of stunting in children aged 0–4 years*, which provides a valuable measure of the effectiveness of interventions aimed at relieving malnutrition.

Other possible action indicators include:

- the *scope and extent of regulations on environmental chemical release and disposal,* which indicates the effectiveness of action to reduce exposures to hazardous chemicals affecting the newborn child;
- the *extent and scope of nutritional education programmes,* which is an indicator of the level of support offered to mothers on effective nutrition;
- the number of *women of childbearing age vaccinated against rubella infection,* which provides a measure of the effectiveness of maternal vaccination programmes.

3.3.2 Respiratory diseases

After perinatal diseases, respiratory illness represents the most important source of ill-health and mortality among young children. The main component of this burden comes from acute respiratory infections (ARI), both by viruses and bacteria: amongst these, bacterial pneumonia, an infection of the lungs, takes the largest toll. In early childhood, however, other risk factors are also important, and respiratory syncytial virus (RSV) and para-influenza virus type 3 tend to dominate. Other important respiratory diseases include measles, whooping cough and asthma.

Given effective and well-resourced systems of health care, these diseases need rarely be fatal. In the developing world, however, lack of adequate care, or poor access to the available care because of problems such as remoteness or poverty, mean that death is all too common. Globally, respiratory diseases account for more than 2 million deaths each year among children under five, the overwhelming proportion in developing countries (WHO 2002).

Figure 9. Respiratory diseases

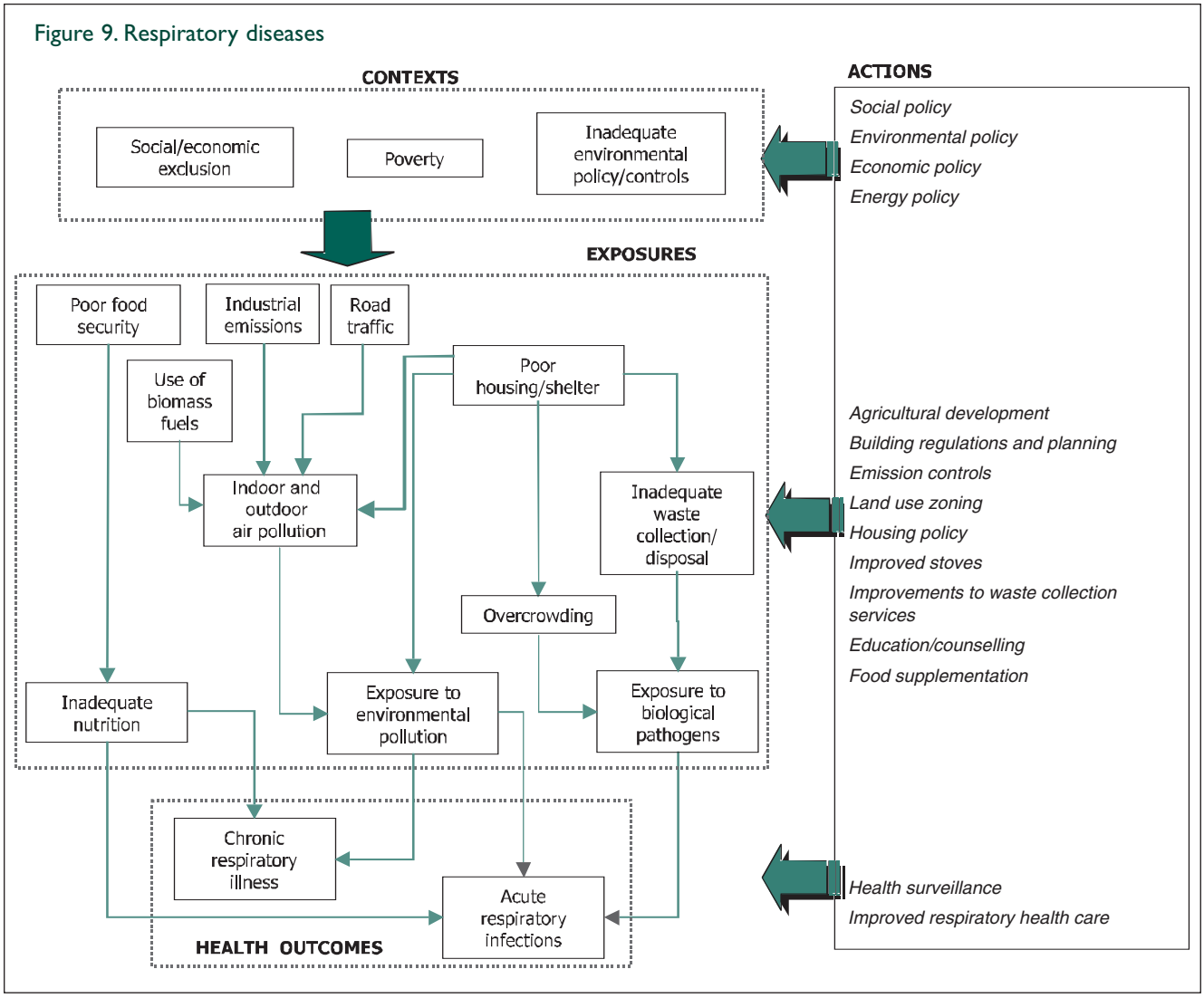


Figure 9 summarizes the issue of respiratory illness. ARI tends to be the main concern, and takes many forms. Globally, bacterial pneumonia is the most important, but viral infections, measles, whooping cough and a wide range of allergies (e.g. rhinitis) are also widespread. Chronic respiratory illness, in particular asthma, is also a growing problem in many parts of the world, in part as a result of exposures to ambient and indoor air pollution.

On a national scale, distinguishing between these various forms of respiratory illness is rarely necessary. Three main health effect indicators may therefore be defined:

- *mortality rate due to acute respiratory illness in children aged 0–4 years;*
- *morbidity rate due to acute respiratory illness of children aged 0–4 years;*
- *prevalence of chronic respiratory illness in children aged 0–14 years.*

Where appropriate, however, more specific indicators relating to individual forms of respiratory infection can be used.

Many different environmental risk factors are implicated in these diseases. As already noted, some, such as the bacteria causing pneumonia, are more or less ubiquitous; risks are therefore dependent mainly on the ability of children or their mothers to

Key indicators of respiratory diseases

Contexts

Number of children aged 0–14 years living in poverty

Exposures

Children aged 0–14 years living in unsafe, unhealthy or hazardous housing

Overcrowding

Children aged 0–14 years living in proximity to heavily trafficked roads

Mean annual exposure of children aged 0–14 years to atmospheric particulate pollution

Children aged 0–14 years living in households using biomass fuels or coal as the main source of heating and cooking

Children aged 0–14 years living in households in which at least one adult smokes on a regular basis

Intrauterine growth retardation in newborn children

Health outcomes

Mortality rate of children aged 0–4 years due to acute respiratory illness

Morbidity rate of children aged 0–4 years due to acute respiratory illness

Prevalence of chronic respiratory illness in children aged 0–14 years

Actions

Attributable change in numbers of households depending on biomass fuels or coal

Attributable change in tobacco consumption

Attributable change in atmospheric pollutant concentrations

resist infection. As well as genetic factors and the general state of health, social and environmental conditions may be important in this respect. Inadequate diet, poor housing and overcrowding may all contribute to reducing resistance. Because children spend most of their time at home, indoor exposures to air pollution are also extremely important. Not all indoor exposures derive from indoor emission sources, but burning of biomass fuels (especially in poorly ventilated fires or stoves) and environmental tobacco smoke are often major culprits. In some cases, too, exposures to industrial or traffic emissions pose significant threats.

Key indicators thus include:

- the prevalence of *intrauterine growth retardation in newborn children,* which provides an indicator of the risks associated with impaired fetal growth;
- the number of *children aged 0–14 years living in households using biomass fuels or coal as the main source of heating and cooking*, which provides an indicator of risks from indoor emission sources;
- the number of *children aged 0–14 years living in households in which at least one adult smokes on a regular basis,* which is an indicator of exposures to environmental tobacco smoke;
- the *mean annual exposure of children aged 0–14 years to atmospheric particulate pollution,* which provides an indicator of risks from ambient air pollution (especially from road traffic and industry).

Exposures to these various risk factors provide the proximal causes of acute respiratory infection, and account for a large proportion of the disease burden. Beyond them, however, often lie other more fundamental problems. Poor housing, inadequate waste management and poor regulation of emissions from industry and road traffic are all important, albeit more distal, causal factors. As with most forms of childhood illness, poverty is also a major risk factor. Additional indicators thus include:

- the level of *overcrowding,* which provides a measure of overcrowding and consequent risks of infection;
- the number of *children aged 0–14 years living in unsafe, unhealthy or hazardous housing,* which gives a general indicator of risks from poor housing;
- the number of *children aged 0–14 years living in proximity to heavily trafficked roads,* which gives a measure of exposures from road traffic emissions;
- the number of *children aged 0–14 years living in poverty* — a general indicator of non-specific risks due to socio-economic deprivation.

Actions to tackle these risks can be taken in many different ways. Obviously, policies aimed at reducing exposures to pollutants and allergens both inside and outside the home are potentially effective tools. Actions to improve general well-being and nutrition of both mothers and children are also important. Key action indicators thus include:

- the number of *children aged 0–14 years with access to prompt antibiotic treatment for pneumonia,* which provides an indicator of the ability quickly and effectively to combat pneumonia;
- the *attributable change in the number of households depending on biomass fuels or coal,* which is an indicator of the effectiveness of energy policies;
- the *attributable change in tobacco consumption,* which provides a measure of the effectiveness of policies aimed at reducing smoking;
- the *attributable change in air pollution concentrations,* which provides a measure of the degree to which actions to reduce ambient air pollution are having an effect.

3.3.3 *Diarrhoeal diseases*

Diarrhoeal diseases are a worldwide problem. Like most other diseases of children, however, they are far more prevalent in the developing world than in developed countries — 12.5 times more so in the case of mortality (WHO/EIP, unpublished). Children below the age of five are especially susceptible, and among the many forms of disease that they may encounter, by far the most severe, in terms of their clinical manifestations, are cholera, rotavirus infections and dysentery.

At a general level, two health effect indicators can readily be proposed: one relating to the rate of mortality due to diarrhoeal diseases, and the other to morbidity. In addition, however, because of the episodic nature of diarrhoeal diseases, a third indicator is also often useful, relating to the number of disease outbreaks (an outbreak is usually defined as an occurrence of two or more linked cases of the same illness, or an increase in the number of observed cases over the expected number). Thus, the following health effect indicators are proposed:

- the *diarrhoea mortality rate in children aged 0–4 years;*
- the *diarrhoea morbidity rate in children aged 0–4 years;*
- the *recurrence rate of outbreaks of diarrhoeal disease among children aged 0–4 years.*

The primary causes of diarrhoeal diseases are bacterial or viral infections. Major pathways of infection are via human or animal faeces, food, water and human contact. Environmental conditions that provide habitats or hosts for pathogens or increase the likelihood of contact thus act as major risk factors. Poor domestic sanitation and hygiene, lack of safe drinking water, and exposures to solid wastes (e.g. through waste picking or waste accumulation in the neighbourhood) are therefore all implicated. These in turn are often associated with poor facilities for waste and water management, lack of adequate safety procedures within the food supply system (e.g. during livestock management, food storage and retailing), and inadequate control of environmental pollution (e.g. by agricultural wastes). Epidemics may also occur as a result of major pollution episodes or natural disasters, such as floods. Droughts may similarly cause outbreaks due to the build-up of pathogens in water courses and the need for domestic water storage (often under inadequate conditions). Beyond these lie many of the more generic causes of ill health in children — poverty, social exclusion and poor environmental policies and controls (Figure 10).

Against this background, one of the most useful, general exposure indicators is:

- the number of *children aged 0–14 years living in households without basic services for water supply, sanitation and hygiene*, which provides a measure both of the reliability and quality of available water and of the level of sanitation, hygiene, waste disposal and food storage in the home.

Where needed, however, more specific indicators can be defined that focus on particular sources of risk. Examples include:

- the number of *children aged 0–14 years living in households without access to adequate amounts of safe drinking water;*
- the number of *children aged 0–14 years living in households without safe food storage and handling facilities;*
- the number of *children aged 0–14 years living in households without access to adequate excreta disposal facilities;*
- the number of *children aged 0–14 years living in households without bathing facilities;*
- the number of *children aged 0–14 years living in households not served by regular municipal waste collection services.*

Key indicators of diarrhoeal diseases

Contexts

Children aged 0–14 years living in poverty

Exposures

Drinking water supplies failing national microbiological water quality standards

People living in informal settlements

Children aged 0–14 years living in disaster-affected areas

Children aged 0-14 years living in households without basic services for water supply, sanitation and hygiene

Health outcomes

Diarrhoea mortality rate in children aged 0–4 years

Diarrhoea morbidity rate in children aged 0–4 years

Recurrence rate of outbreaks of diarrhoeal disease among children aged 0–4 years

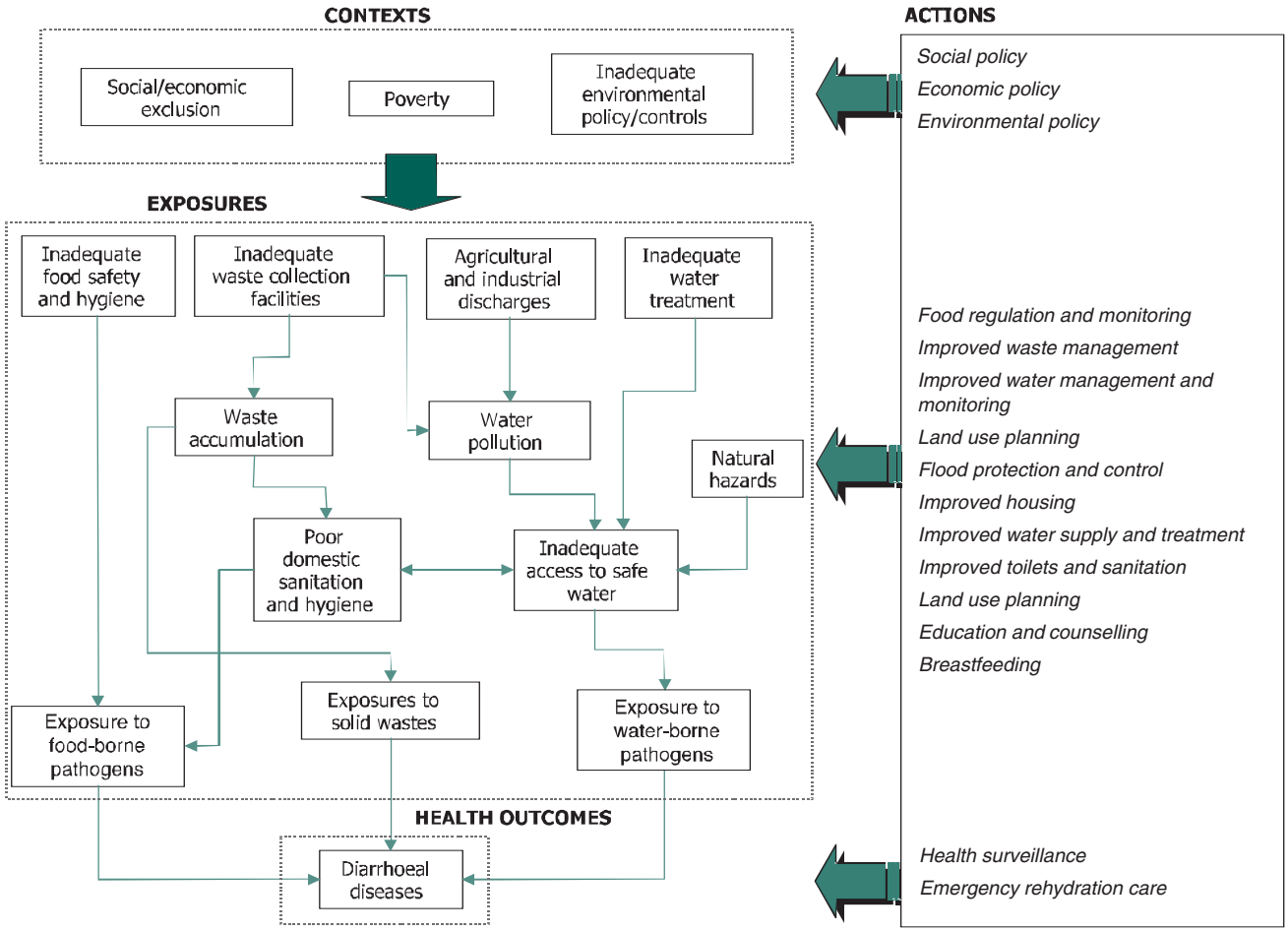
Actions

Attributable change in the number of households lacking basic services

Attributable change in number of food outlets failing food hygiene standards

Children aged 0–4 years able to obtain rehydration therapy within 24 hours of need

Figure 10. Diarrhoeal diseases



As with other issues, deeper problems lie behind these proximal risk factors. These include pressures on the environment such as uncontrolled releases of pollutants in surface and ground waters, and more remote driving forces such as poor housing, inadequate infrastructure and poverty. Problems tend to be worst in informal settlements. They are also made more acute in some cases by external events, such as floods or war. Additional indicators may therefore be defined for these more distal factors, for example:

- the percentage of *drinking water supplies failing national microbiological water quality standards;*
- the number of *people living in informal settlements;*
- the number of *children aged 0–14 years living in disaster-affected areas;*
- the number of *children aged 0–14 years living in poverty.*

Actions to mitigate risks from diarrhoeal diseases obviously need to be targeted at the underlying environmental and social problems that create the conditions for disease. Improvements to water supply, sanitation, waste management and food hygiene thus need to take precedence. In the short term, however, there is also a need to deal with more immediate crises. Rapid and effective response is then of the essence, for many diarrhoeal diseases kill quickly. Diarrhoea death rates can be greatly reduced by ensuring that oral rehydration therapy is quickly applied. Programmes aimed at providing these quick response facilities (including the training to deliver them) are therefore vital forms of action. By the same token, education in

personal and food hygiene are important measures to reduce risks. Key action indicators thus include:

- the *attributable change in the number of households lacking basic services,* which is a measure of the effectiveness of policies aimed at improving domestic facilities;
- the *attributable change in number of food outlets failing food hygiene standards,* which provides an indication of the effectiveness of food protection measures;
- the number of *children aged 0–4 years able to obtain rehydration therapy within 24 hours of need.*

Again, where appropriate, the first of these may be defined more specifically in terms of access to individual amenities, such as a safe and reliable water supply, excreta disposal facilities, waste collection and food storage. A potential additional action indicator is:

- the *number of households receiving free education and guidance on personal and food hygiene.*

3.3.4 *Insect-borne diseases*

A wide range of insect-borne diseases threaten children. Dengue, onchocerciasis, leishmaniasis and sleeping sickness all take a large toll, though for children by far the greatest cause for concern is malaria. Today, even after decades of control and eradication campaigns, malaria is still endemic in about one fifth of the world. Some 2 billion people are at risk; as many as 200–300 million young children may be infected, of whom almost 1 million die annually. Africa is by far the worst affected region, accounting for about 90% of the total disease burden due to malaria amongst children under 5 years of age. Here, especially, the trend is upward.

Many of these diseases are the result of complex transmission pathways, often involving a range of different carriers and hosts. The prevalence of these various diseases varies greatly from one part of the world to another, so specific indicators — reflecting the particular diseases of concern and their transmission pathways — need to be defined. Here, however, the focus is on outlining generic indicators that have more widespread use. These can (and should) be adapted and developed locally as needed. Key health effect indicators are thus:

- the *mortality rate due to insect-borne diseases among children aged 0–4 years;*
- the *prevalence of insect-borne diseases in children aged 0–14 years.*

Although many different insects may be involved in disease transmission, the mosquito carries the major share of blame — though, in truth, mainly as an innocent agent of human folly. For while the distribution of disease carriers obviously determines to a large extent the distribution and intensity of diseases, the carriers' own distribution and spread are determined primarily by the availability of hosts and habitats, which, in turn, are governed by human action (Figure 11). Land use change, irrigation, drainage, water development, road development and forest clearance have created new habitats for mosquitoes and other insect vectors in some areas, and helped insect-borne diseases to spread. Loss of impetus in control programmes has enabled diseases to regain a hold in areas from which they had been eradicated. Poor housing, inadequate waste management, domestic water storage, and ineffective sanitation and hygiene all contribute to risks of infection. Famine, war, oppression and development have also acted as forces for displacement, driving or drawing populations from non-endemic into endemic areas. In the longer term, climate change may add to these problems, by encouraging further shifts in the insect vectors as well as mass human migration. For children of the future as much as those of today, therefore, the prognosis remains bleak.

Standards, guidelines and indicators

The *percentage of drinking water supplies failing national microbiological water quality standards* is suggested here as an indicator of potential exposures from drinking water contamination. Indicators such as this, that use an established standard or guideline as a reference, are well-established. Indeed, some authorities have argued that all indicators should incorporate either a formal standard or an agreed target level.

Where internationally approved standards, guidelines or targets exist, this certainly has some merit. Where they do not, indicators like this pose difficulties. Clearly, they may not be directly comparable between different countries because the standards vary. There is also the danger that they will be deliberately manipulated to 'improve' the situation (statistically if not in reality), for example by using less rigorous standards – or by sampling in less contaminated locations. Against these problems, however, must be set the advantages of allowing such flexibility, for this allows indicators to be customized to the circumstances that prevail in each country. Where international comparisons are intended, however, efforts should be made to standardize the indicators – for example, by translating them to a common reference.

Key indicators of insect-borne diseases

Contexts

Population growth rate in areas endemic for insect-borne diseases

Exposures

Total area of insect vector habitats

Children aged 0–14 years living in households providing suitable conditions for insect disease transmission

Children aged 0–14 years living in areas endemic for insect-borne diseases

Health outcomes

Mortality rate of children aged 0–4 years due to insect-borne diseases

Prevalence of insect-borne diseases in children aged 0–14 years

Actions

At-risk children aged 0–14 years covered by effective, integrated vector control and management systems

Exposures to these diseases occur primarily because children are bitten by the relevant carrier insect (though, in some cases, maternal transmission is also possible). Probably the most useful indicator of exposure is thus:

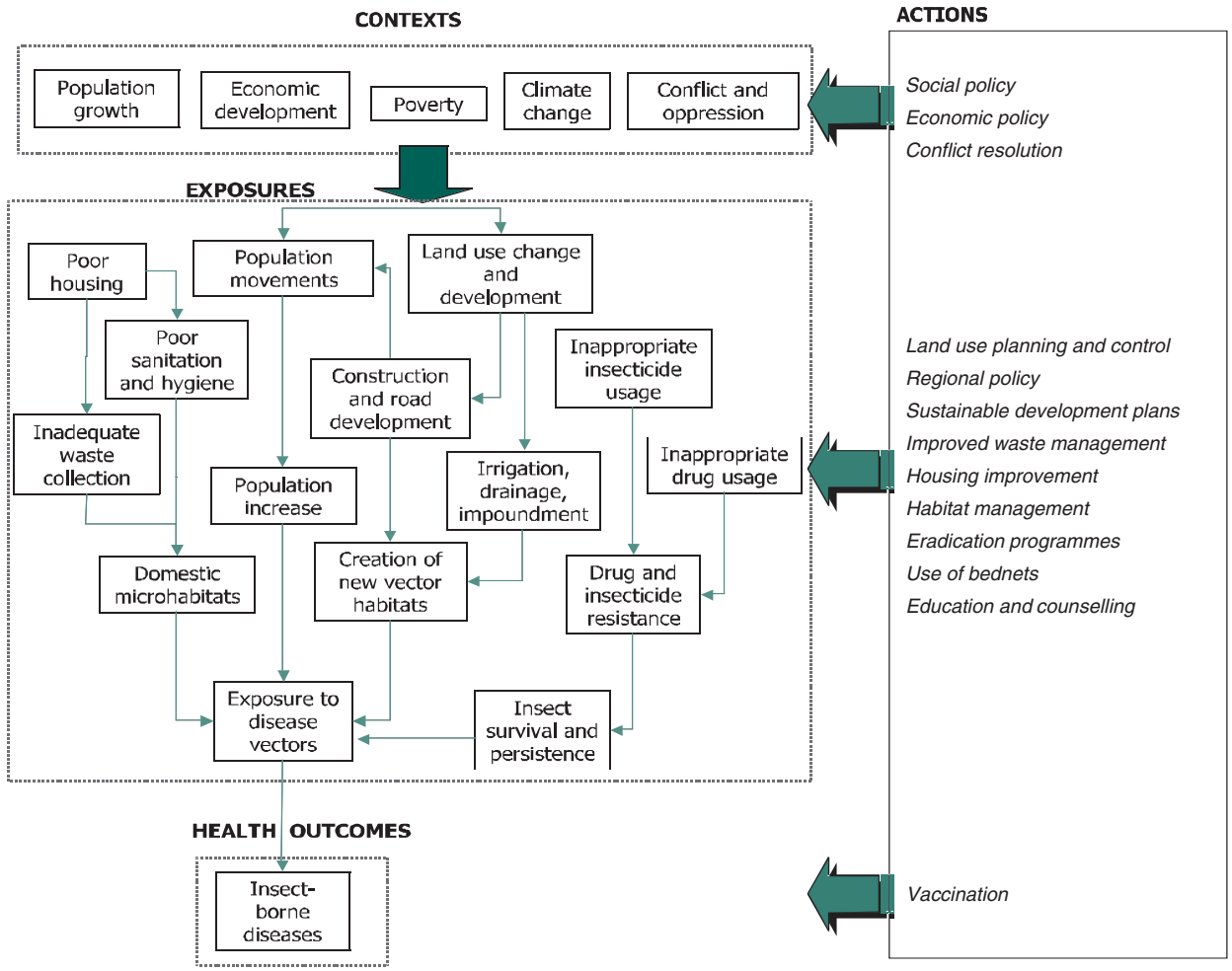
- the number of *children aged 0–14 years living in areas endemic for insect-borne diseases,* which provides a general measure of the risk of infection.

In some cases, however, more specific exposure indicators can be developed, based for example on knowledge about vector intensities (e.g. numbers of breeding insects) or the entomological inoculation rate.

The distribution of insect-borne diseases, more generally, is dependent on the availability and extent of suitable habitats. As noted, these are widely influenced by land use practices and development. The availability of domestic micro-habitats in which the insects can breed, feed and take refuge is likewise important. And, more remotely, factors such as housing conditions, overcrowding, population growth and climate change also have an effect. Other useful indicators thus include:

- the *total area of insect vector habitats,* which may be defined to include the extent of all favourable breeding grounds (depending on the insects concerned);

Figure 11. Insect-borne diseases



- the number of *children aged 0–14 years living in households providing suitable conditions for insect disease transmission,* which may be defined to include all relevant microhabitats, such as open water storage facilities, open waste sites, open latrines or livestock, as well as use of preventative measures such as sleeping nets;
- the *population growth rate in areas endemic for insect-borne diseases,* which provides a measure of the population pressure in areas of disease endemism.

Three main approaches to the control of insect-borne diseases can be distinguished. The first is through habitat control, with the intention of reducing opportunities for breeding and transmission. The second is through the use of pesticides or other methods to eliminate the insects themselves (though these can pose health risks in their own right). The third is via vaccination of populations at risk. All three, to varying degrees, may be necessary and effective. The best strategies, however, are likely to be integrated measures that combine some element of all three. The most appropriate action indicator is thus:

- the number of *at-risk children aged 0–14 years covered by effective, integrated vector control and management systems,* which provides a measure of the extent of current integrated control programmes.

Where appropriate, however, other more specific indicators can be used, for example:

- the number of *children aged 0–14 years effectively inoculated against insect-borne diseases;*
- the *decennial rate of change in the area of insect vector habitats;*
- the percentage of *infected households treated against insect vectors,* which may be defined to include not only insecticide treatment but also measures to remove domestic microhabitats and self-protective measures such as use of sleeping nets;
- the *area of land under insect vector control or eradication programmes.*

3.3.5 Physical injuries

Of all forms of illness, injuries to children are perhaps the most pernicious. At best, they reflect individual or collective neglect; at worst, they are the product of deliberate and callous abuse.

Injuries occur for many reasons, and take many forms. They include drowning, road accidents, falls and burns, accidental poisonings and injury as a consequence of natural events such as earthquakes or storms. Often these may seem to be chance occurrences, and therefore excusable. In the case of some natural hazards, this may be true. More frequently, however, though chance plays some part in the timing or location of specific events, deeper social or environmental causes are at work, which are at least in part preventable. Avoidable risk factors, typically, include poor housing, lack of adequate play space, child labour, and exposures to wastes and chemicals (Figure 12). Reducing risks of unintentional injuries is therefore largely a matter of effective planning and education: planning to create environments in which children can live and play in safety; education to help them and the adults on whom they rely to appreciate better the hazards that exist.

In terms of health effect, therefore, two general indicators can be defined:

- the *mortality rate of children aged 0–14 years due to physical injuries;*
- the *incidence of physical injuries to children aged 0–14 years requiring treatment.*

Russian dolls

In trying to make inter-country comparisons there is almost always a tension between generality and specificity. The issues of concern vary from one country to another. If we define indicators that are highly specific for one area or country, they may well be irrelevant in others. On the other hand, general indicators may mask as much as they reveal.

This is especially true in the case of insect-borne diseases. Many different insects act as carriers for disease, most of them with very particular lifecycles and habitats. The risk factors for one disease are thus not the same as for another. By the same token, many of these insects, and the diseases they carry, have specific geographic distributions.

This is a common dilemma, but it has been solved before in other disciplines. The answer lies in nesting — in developing indicators that sit, like Russian dolls, one within another. Thus here, we have deliberately concentrated on developing generic indicators. Individual countries, however, will wish to customize these to the specific diseases and transmission pathways of relevance to them. But so long as these more local indicators nest within the broader ones presented here, they can always be aggregated upwards to allow inter-country comparisons.

Key indicators of physical injuries

Contexts

Children aged 0–14 years living in poverty

Exposures

People living in informal settlements

Children aged 0–14 years living in disaster-affected areas

Children aged 0–14 years living in proximity to heavily trafficked roads

Children aged 0–14 years involved in routine employment

Children aged 0–14 years living in unsafe, unhealthy or hazardous housing

Children aged 0–14 years living in homes lacking access to a piped water supply

Health outcomes

Mortality rate due to physical injuries to children aged 0–14 years

Incidence of physical injuries to children aged 0–14 years requiring treatment

Actions

Children living aged 0–14 years within reach of specialist emergency health care

Attributable change in injuries to children aged 0–14 years requiring treatment

However, for more specific applications, it may be necessary to define indicators more narrowly by injury source or type, as follows:

- the *incidence of poisonings in children aged 0–14 years;*
- the *road traffic injury rate of children aged 0–14 years;*
- the *mortality rate of children aged 0–14 years due to road accidents;*
- the *incidence of injuries to children aged 0–14 years due to falls and burns;*
- the *incidence of mortality of children aged 0–14 years due to drowning;*
- the *incidence of injuries to children aged 0–14 years due to animal attacks and bites;*
- the *incidence of injuries to children aged 0–14 years due to accidents at work.*

Each of these outcomes implies exposure to a specific form of risk. More general exposure indicators can, however, also be identified.

- The number of *children aged 0–14 years living in proximity to heavily trafficked roads* provides an indicator of exposures to road traffic accidents.
- The number of *children aged 0–14 years involved in formal or informal employment* gives an indicator of exposures of children to accidents at work.
- The number of *children aged 0–14 years living in unsafe, unhealthy or hazardous housing* is an indicator of exposures to physical hazards in the home.
- The number of *children aged 0–14 years living in homes lacking access to a piped water supply* indicates the risk of drowning due to the need to rely on open water courses as a source of water and bathing.

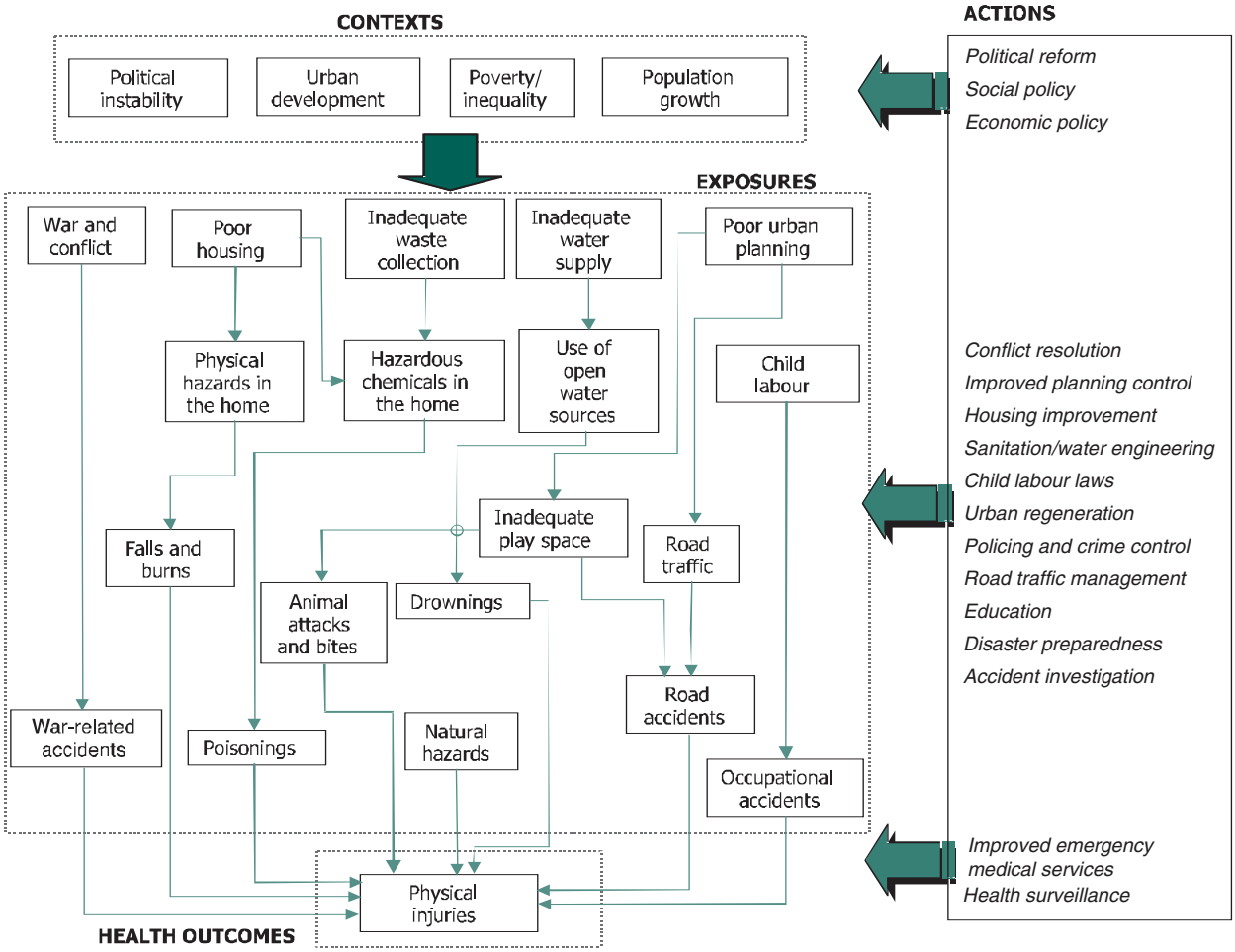
More remote factors contributing to these risks include social unrest, natural hazards, poor housing and poverty. Other indicators of risks of injuries thus include:

- the number of *people living in informal settlements;*
- the number of *children aged 0–14 years living in disaster-affected areas, which may be defined to include areas of natural hazards and war;*
- the number of *children aged 0–14 years living in poverty.*

Actions to reduce these risks are varied. General policies aimed at reducing poverty and improving living conditions are certainly important. Many of the most effective measures, however, are more specific. They include actions to reduce road traffic speeds, to make packaging of hazardous chemicals clearer and safer, to limit use of child labour, to improve housing safety and to provide easier access to specialist health care, such as poisons units. Capturing the effects of these different actions in a single indicator is difficult, and specific action indicators may be necessary. The following more general indicators can nevertheless be suggested:

- the number of *children aged 0–14 years living within reach of specialist emergency health care*, which can be defined to include access to both accident and emergency and poisons units;
- the *attributable change in injuries to children aged 0–14 years requiring treatment,* which provides a general measure of the effectiveness of interventions aimed at protecting children from injury.

Figure 12. Physical injuries



3.4 Indicator design

The provisional list of indicators outlined above comprises some 60 indicators, covering the five issues of concern. Several of the indicators (especially those relating to the contexts of risk) are duplicates. Even so, there are at present around 50 different indicators within the list.

For many, this will already seem overlong. Those who commission and request indicators (especially policy makers) often expect, and may demand, a very short list — in some cases a single indicator. The reality, unfortunately, is that the world is complex, and we need to acknowledge this complexity, and use information to match, if we are to intervene effectively. If we try to reduce this complexity to a tiny set of indicators we may well lose more in terms of knowledge than we gain in ease of application or savings in cost. Either we will end up with a sparse set of indicators that fail to tell us all we need to know and which bias our perceptions and actions, or we will have a few highly aggregated indicators that include everything but hide it within an unfathomable index.

The importance of metadata

Metadata are data about data – they tell us what data exist, what form they take, and how to obtain them. Two forms of metadata can in fact be recognized:

- Discovery metadata— which help us to find out what data are available and what information they can provide;
- Access metadata — which help us to locate and acquire the data.

Both forms of metadata are crucial if we are to make the best use of the data that exist. Sadly, both are often inadequate.

One reason for this is that describing data effectively is complex. We usually need to know more than that we can obtain data on health from the health ministries, or data on air pollution from the air quality agencies – we need to know exactly what form these data take, how they have been compiled, for which areas and time periods they are available, what format they are in and how to obtain them (and what the cost will be).

A second reason is often that those who hold data have little incentive to make their data readily available to other users (and may even see dangers in doing so) — though fortunately the Internet is helping to change this attitude.

At the same time, we should note that several variations on the indicators proposed here have already been suggested. We have also recognized the need to customize or extend the indicator set according to circumstances. The list is therefore likely to grow further as the indicators are adapted and used. Those who want to encapsulate reality in one simple, all-encompassing indicator are thus likely to remain disappointed.

In practical terms, in any case, the length of the list of indicators is not what matters most. Most indicators are merely visualizations of underlying data. To produce them, we simply manipulate, integrate, process and represent in an appropriate form data that already exist. With modern computers, even with large data sets, this need not take long. Provided the relevant scientific knowledge and data are available, well-designed indicators can thus be readily constructed, at little cost. Furthermore, many of the indicators developed draw upon the same basic knowledge and data. This also helps to reduce the costs of developing indicators and makes the process of maintaining indicator sets less daunting than it might otherwise seem.

3.4.1 Data availability

More important than the number of indicators is the question of data availability. It is this that usually poses the greater difficulties and determines how feasible and practicable any list of indicators really is. Problems of accessing the data that do exist, for example, can greatly hamper indicator development, and add substantially to administrative costs. Differences in data formats (and poor metadata) can likewise cause problems. If suitable data do not exist, or cannot be obtained, much effort may need to be spent on trying to find alternatives. Gaps, errors, or lack of consistency in the data can be costly to identify and resolve. Before attempts are made to translate indicator specifications into detailed designs it is therefore essential to assess their data needs and to see to what extent these can be met. (After all, which designer would develop specifications for a new product without considering whether the materials needed to manufacture it are available?) Where the necessary data are not available, three choices exist:

- to change the indicator to match the data that are available;
- to find alternative data that can act as proxies; or
- to abandon the indicator.

The reiterative nature of this process needs to be recognized. At this stage, we have not yet specified the details of each indicator — for example, the geographic scale or level of aggregation, the averaging period, or even the specific definition. To gain time, however, these details need to be developed within some sort of understanding of data availability: otherwise, we are likely to design indicators that cannot be constructed. In considering data issues now, we must therefore look ahead to the shape that some of these details will take. We must start to juggle the two constraints of practicality and need in order to end up with a set of specifications, including their data requirements, that are both feasible and cost-effective, yet allow the indicators as far as possible to achieve their purpose. As we go through this process we can also begin to assess the potential to merge different indicators for the sake of data economy.

Tables 1–5 summarize the data needs for the proposed indicators, together with suggestions of potential data sources. It is evident that the data needed to generate these indicators are clearly substantial, but also that there are many opportunities for data sharing. In particular, four main sets of data have general importance:

- census data, giving information on the distribution of population by age and gender as well as other socio-economic data;
- mortality data, giving information on death by cause;
- health care data (including hospital admissions), giving information on cause of admission and/or treatment;
- housing data, giving information on the condition and type of housing and residential facilities.

Several of the other data sets needed are also likely to be available from routine reporting by the agencies and authorities concerned (e.g. water companies, aid agencies). Others, however, are likely to derive only from special surveys (e.g. household surveys) or environmental monitoring.

Meeting all these data requirements obviously poses difficulties, especially in less developed countries that lack fully developed reporting systems. In many instances, also, the major constraint is not so much the absence of data, but their inappropriateness for these indicators — for example because of their level of aggregation, their timing, or inconsistencies in their format and detailed definition. This arises especially where there is a need — as is often the case with indicators — to link data from different sources. Harmonizing the data that exist, as much as collecting new information, is often a major priority if we wish to improve our capability to develop and use indicators.

In all these cases, there are various ways of filling the gaps. In the long term undoubtedly, the most effective is to set up the necessary monitoring, surveillance and reporting systems that currently do not exist. Indeed, one of the most important benefits of trying to establish indicators is that they often highlight where the most important information gaps occur and thereby encourage targeted action to fill them. This, however, can inevitably be costly and will certainly take time. The main alternative is to seek proxy indicators that can make use of available data sources. Lacking quantitative data on health outcome, for example, we might still be able to derive qualitative measures by drawing on the experience of health professionals. Lacking direct measurements of environmental conditions, we might be able to use modelling techniques to estimate them. Increasingly, such models are available free on the Web. Satellite data provide an ever more reliable way of obtaining a wide range of information on the environment (e.g. on land use, urbanization, housing conditions, natural hazards and pollution). If we cannot afford to conduct national surveys, we might nevertheless be able to design and carry out smaller, sample studies. Each of these proxies needs to be used with care: professional opinions need to be verified by triangulation; models should be validated against field data; sample surveys must be carefully stratified so that they can be reliably extrapolated to a wider area or population. But in the absence of other options, they can be far better than no data at all.

Nevertheless, the key message remains: if we want to develop and use indicators we must be prepared to invest in the data collection and processing needed to construct them. It is a point made already, but it merits repeating. Indicators do not replace the need for data. Indeed, just the opposite, they add to it.

A reduced indicator set

One of the common pleas of users when confronted with a long list of indicators is to reduce it to a more manageable 'core' set of indicators. In the case of environmental health we should treat this request with caution. The reason why the lists of indicators tend to be long is that the world is complex, and the questions we ask are varied. Reducing the indicator set means losing information (and inevitably fails to satisfy some users).

We can, however, identify a number of indicators that contain rather more information than the others. These are the ones that relate to several different issues, or are sufficiently generic to have general applicability.

In relation to exposures, candidates for this reduced set are:

- *number of children living in poverty*
- *number of children living in unsafe, unhealthy or hazardous housing*
- *number of children living in households without basic amenities for water supply, sanitation and hygiene*

In relation to health outcomes they include:

- *number of newborn children affected by intrauterine growth retardation*
- *perinatal mortality rate*
- *all cause infant mortality rate*

In terms of actions, they are indicators of change in these key environmental and health conditions.

Table 1. Indicators and data needs: perinatal diseases

INDICATOR	DATA NEEDS	POTENTIAL DATA SOURCES
Contexts		
Children aged 0–14 years living in poverty	Number of children aged 0–14 years by household income Costs of basic needs	Census data, tax registers or household surveys
Exposures		
Famine risk	Extent of current or imminent famines Total number of women aged 16–45 years	Agency or scientific reports
People living in informal settlements	Population in informal settlements Total population	Census data or household surveys
Women of childbearing age who are malnourished	Numbers of women aged 15–49 years by nutritional status	Nutritional surveys
Women of childbearing age working in unregulated workplaces	Numbers of female employees aged 15–49 years in unregulated workplaces Total number of women aged 15–49 years	Census or employment data, or household surveys
Births to mothers living in unsafe or hazardous housing	Birth rate by place of mother's residence and housing condition	Birth registrations, linked to census data or household surveys
Health outcomes		
Perinatal mortality rate	Number of deaths in the perinatal period Total number of births (including live and still births)	Death registers
Intrauterine growth retardation in newborn children	Numbers of births by birth weight, gestational age and gender	Health surveillance systems
Congenital malformations requiring surgical correction in children under 1 year of age	Incidence of congenital malformations in children under 1 year of age	Health surveillance systems
Actions		
Women of childbearing age within one hour's travel of specialist maternity and perinatal care	Place of residence by gender and age Location of specialist maternity and perinatal care units Transport facilities	Census data linked to health service data, or household surveys
Attributable change in number of households lacking basic services	Numbers of households provided with reliable and safe drinking water, excreta disposal facilities, waste collection	Census data or housing condition surveys
Prevalence of stunting in children aged 0–4 years	Numbers of children by body weight, height, gender and age	Nutritional and household surveys

Table 2. Indicators and data needs: respiratory diseases

INDICATOR	DATA NEEDS	POTENTIAL DATA SOURCES
Contexts		
Children aged 0–14 years living in poverty	Number of children aged 0–14 years by household income Costs of basic needs	Census data or household surveys
Exposures		
Children aged 0–14 years living in unsafe, unhealthy or hazardous housing	Number of children aged 0–14 years living in unsafe, unhealthy or hazardous housing Total resident population of children aged 0–14 years	Linkage of census data to data from housing condition surveys, or household surveys
Overcrowding	Total floor area in occupied dwellings Total resident population	Census data or household surveys
Children aged 0-14 years living in proximity to heavily trafficked roads	Road network Traffic volumes Place of residence Numbers of children aged 0–14 years	Linkage of census data and highways data
Mean annual exposure of children aged 0–4 years to atmospheric particulate pollution	Mean annual concentrations of PM_{10} at a standard height (usually ca. 2 metres, Numbers of resident children aged 0–4 years	Linkage of census data to air quality maps (modelled or interpolated from monitoring sites)
Children aged 0–4 years living in households using biomass fuels or coal as the main source of heating and cooking	Numbers of children aged 0–4 years by character of fuel usage in the home	Census data or household surveys
Children aged 0–14 years living in households in which at least one adult smokes on a regular basis	Number of households in which at least one adult smokes on a regular basis Total number of children aged 0–14 years, living in these households Total number of children aged 0–14 years in the survey area	Household surveys
Intrauterine growth retardation in newborn children	Number of births by birth weight, gestational age and gender Total number of live births	Health surveillance systems Special surveys
Health outcomes		
Mortality rate for children aged 0–4 years due to acute respiratory illness	Annual number of deaths of children aged 0–4 years due to acute respiratory infections. Total number of children aged 0–4 years at the mid-point in the survey year	Death registers
Morbidity rate for children aged 0-4 years due to acute respiratory illness	Number of cases of acute respiratory infection in children aged 0–4 years Total number of children aged 0–4 years	Health surveillance systems
Prevalence of chronic respiratory illnesses in children aged 0-14 years	Reported rate of chronic respiratory diseases among children aged 0–14 years Total number of children aged 0–14 years	Health surveillance systems
Actions		
Attributable change in tobacco consumption	Tobacco sales Total number of adults	Consumer surveys or sales data
Attributable change in atmospheric pollutant concentrations	Daily (or hourly) concentrations of PM_{10}, SO_2, NO_2 and O_3 at a representative sample of monitoring stations	National emissions inventories
Attributable change in numbers of households relying on biomass fuels or coal as the main source of heating or cooking	Numbers of households by character of heating and cooking facilities in the home	Census data or housing condition surveys

Table 3. Indicators and data needs: diarrhoeal diseases

INDICATOR	DATA NEEDS	POTENTIAL DATA SOURCES
Contexts		
Children aged 0–14 years living in poverty	Number of children aged 0–14 years by household income Costs of basic needs	Census data or household surveys
Exposures		
Drinking water supplies failing national microbiological water quality standards	National water quality standards Number of water samples tested Number of samples failing water quality standards	Water company reports/ statistics
People living in informal settlements	Population in informal settlements Total population	Census data or household surveys
Children aged 0–14 years living in disaster-affected areas	Number of resident children aged 0–14 years Extent of disaster-affected areas	Linkage of census data to environmental survey data and aid agency data
Children aged 0–14 years living in households without basic services for water supply, sanitation and hygiene	Number of households with basic sanitation, water supply and waste disposal services Total number of children aged 0–14 years by household	Linkage of census data to housing condition survey data, or household surveys
Health outcomes		
Diarrhoea mortality rate in children aged 0–4 years	Total number of deaths due to diarrhoea in children aged 0–4 years Total population of children aged 0–4 years	Death registers
Diarrhoea morbidity rate in children aged 0–4 years	Number of episodes of diarrhoea among children aged 0–4 years Total number of children aged 0–4 years	Health surveillance systems
Recurrence rate of outbreaks of diarrhoeal disease among children aged 0–4 years	Number of outbreaks of diarrhoeal disease affecting children aged 0–4 years Total number of children aged 0–4 years	Health surveillance systems
Actions		
Attributable change in the number of households lacking basic services	Numbers of households provided with reliable and safe drinking water, excreta disposal facilities, waste collection	Census data or housing condition surveys
Attributable change in number of food outlets failing food hygiene standards	National (or local) food hygiene standards Number of retail food outlets inspected Number of outlets failing on each inspection	Ministry or local authority statistics (extrapolated to give estimates of overall number likely to fail standards)
Children aged 0–4 years able to obtain rehydration therapy within 24 hours of need	Location of health workers trained in rapid rehydration therapies Place of residence of mothers Transport routes and facilities	Census data linked to health service data, or household surveys

Table 4. Indicators and data needs: insect-borne diseases

INDICATOR	DATA NEEDS	POTENTIAL DATA SOURCES
Contexts		
Population growth rate in areas endemic for insect-borne diseases	Boundaries of areas endemic for insect-borne diseases Population numbers (for base and latest year)	Linkage of census data with environmental survey data or models
Exposures		
Total area of insect vector habitats	Boundaries (or estimated extent) of areas suitable as stable habitats for insect vectors Total land area	Satellite-derived land cover data, environmental survey data or models (e.g. based on land cover and climate)
Children aged 0–14 years living in households providing suitable conditions for insect-borne disease transmission	Number of children aged 0–14 years by household Classification of households in terms of presence of insect vector microhabitats	Household surveys
Children aged 0–14 years living in areas endemic for insect-borne diseases	Extent of area endemic for insect-borne diseases Distribution and number of children aged 0–14 years	Linkage of census data with environmental survey data or models
Health outcomes		
Mortality rate of children aged 0-4 years due to insect-borne diseases	Number of deaths of children aged 0–4 years due to insect-borne diseases Total number of children aged 0–4 years	Death registers
Prevalence of insect-borne diseases in children aged 0-14 years	Number of children aged 0–14 years diagnosed with insect-borne diseases at the time of survey Total number of children aged 0–14 years	Health surveillance systems
Actions		
At-risk children aged 0-14 years covered by effective, integrated vector control and management systems	Number of children aged 0–14 years at risk Number of children aged 0–14 years covered by effective vector control systems	Linkage of census data, health surveillance data, and local authority/ agency/ ministry data

Table 5. Indicators and data needs: physical injuries

INDICATOR	DATA NEEDS	POTENTIAL DATA SOURCES
Contexts		
Children aged 0–14 years living in poverty	Number of children aged 0–14 years by household income Costs of basic needs	Census data or household surveys
Exposures		
People living in informal settlements	Population in informal settlements Total population	Census data or household surveys
Children aged 0–14 years living in disaster-affected areas	Population by age Extent of areas affected by natural disasters (floods, earthquakes etc) or war	Linkage of census data to environmental survey data and aid agency data
Children aged 0–14 years living in proximity to heavily trafficked roads	Numbers of children aged 0–14 by place of residence Major road network	Linkage of census data and highways data
Children aged 0–14 years involved in routine employment	Number of children aged 0–14 years in routine employment Total number of children aged 0–14 years	Employment statistics Business surveys
Children aged 0–14 years living in unsafe, unhealthy or hazardous housing	Population by age, by housing condition	Linkage of census data to data from housing condition surveys, or household surveys
Children aged 0–14 years living in homes lacking access to a piped water supply	Numbers of children aged 0–14 by water supply status of the home Total number of children	Linkage of census and water company data, or household surveys
Health outcomes		
Mortality rate of children aged 0–14 years due to physical injuries	Number of deaths due to physical injury by external cause, age and gender Total number of children aged 0–14 years by gender	Death registers
Incidence of physical injuries to children aged 0–14 years requiring treatment	Incidence of unintentional physical injuries to children aged 0–14 years, by gender and external cause Total number of children aged 0–14 years, by gender	Health surveillance systems
Actions		
Children aged 0–14 years living within reach of specialist emergency medical services	Location of specialist emergency medical facilities and associated road and air ambulance coverage Numbers of children aged 0–14 by place of residence Road network	Census data linked to health service data, or household surveys
Attributable change in physical injuries to children aged 0–14 years requiring treatment	Number of deaths due to physical injury by external cause, age and gender Total number of children aged 0–14 years by gender	Health surveillance systems Death registers

3.4.2 *Science and understanding*

In listing the indicators we need, we have gone a long way to defining and justifying them. But this is not all. Much yet has to be done to come up with detailed designs. In many cases, for example, we need to define what it is that we will use to represent the indicator. In most instances we may need to explain more clearly the rationale behind the indicator, and why it has been selected. In designing indicators, therefore, we have to take account not only of the practicalities of data availability, but also of the logic and science needed to translate these data into real and meaningful information. In this respect, several aspects of indicator design are especially important. Geography, time, method of computation and presentation, all deserve particular consideration.

Geography. Environmental health is intrinsically geographic. Risks and health effects vary from one place to another, and indicators must reflect this spatial variability. The way they do so, however, depends upon the spatial structures chosen to represent the indicator. Two related aspects of these structures are of special significance: the type of units (what is sometimes referred to as the zone system), and their resolution or scale.

Geographically, indicators can be represented in many different ways – for example by political or administrative area (country, region, health district etc), by environmental zone (climatic zone, pollution zone etc), by points (e.g. monitoring or survey sites), or by some form of regular grid. Each of these spatial units may also vary in terms of their level of aggregation or scale. Administrative regions may clearly be defined at different levels of aggregation, environmental zones may be more or less generalized, and grid cells may be either large or small. Even points may be used to represent areas of different size.

The choice between these is not only a matter of cosmetics in terms of the way we might map the information; it also affects the data we need, and the sort of information that the indicator provides. If we choose to use a very coarse level of aggregation, for example, we will often lose information: we will smooth out variations in the condition of interest and probably lose sight of important hotspots or patterns. It may also limit the potential situations in which we can use the indicator. Choosing a fine level of aggregation, in contrast, helps to retain detail and increase the flexibility of the indicator, but can make computation of the indicator more difficult and more time-consuming. We may also end up with so much local uncertainty in the indicator that, again, we lose sight of the real patterns. This is especially the case when we are dealing with relatively sparse phenomena – such as rare diseases – for in these cases many of our geographic units may contain only small populations; estimates of disease rates will then be highly unreliable and much of the variation we might think we see in the indicator may be nothing more than random noise.

Time. Time, too, is important in designing indicators. Two crucial choices need to be made: the time period (i.e. length of period covered by the indicator as a whole), and the averaging period (i.e. the period covered by each specific value or measurement of the indicator). Again, these choices involve balancing the need for precision and flexibility against ease of reliability and computation. Thus, choosing short averaging periods gives the indicator more detail and discriminating power: for example, it may allow us to identify short-period events that we would otherwise miss. But it tends to increase the amount of noise we have to contend with, and may mean that we cannot readily detect trends in the indicator or may over-react to random fluctuations. It can also add greatly to the costs of indicator construction, simply because of the need to acquire and process larger volumes of data. Similarly, extending the time period covered (i.e. the length of the time series) can help us to identify longer-term trends, but inevitably increases data and processing costs.

Sharing data

The list of indicators presented in Tables 1 to 5 is relatively long. In order to compile each indicator we also usually need several different types of data. The implications for data gathering are, however, less daunting than might at first be assumed. This is because many of the indicators share common data sets or use the same data sources. Most, for example, use the same population data; many of the health effect indicators use data derived from routine health surveillance systems. Several action indicators are merely reformulations, as measures of change, of data otherwise needed for exposure indicators.

This ability to share data has several implications. It means that developing additional indicators may add only a small marginal cost (for it usually costs little to reprocess or reanalyze data, compared to the cost of their collection). It also means that the key factor in many cases is to develop and maintain a large pool of data. So long as these basic data exist, we can often be extremely flexible and imaginative in the indicators we define, and we can adapt and develop them according to need. Therefore it is not so much the indicators that need to be seen as 'core' as the data on which they are based.

Data collection, collation and co-ordination

Access to relevant data remains a major constraint on the development and use of indicators in many countries. In some cases, this reflects lack of basic monitoring and survey by the relevant agencies. Where this is the case, evidence of the need for indicators to tackle problems of children's environmental health can provide pressure to initiate the necessary monitoring. In the interim, proxy data can often be found. Though insufficient as a reliable basis for the indicators in the long term, these can at least help to demonstrate their potential uses and benefits.

More commonly, however, these problems of data availability derive from administrative, political or technical obstacles inhibiting access to data that already exist. These obstacles are rarely insurmountable, if sufficient will exists. The challenge is to generate the will. Indicators actually help in this respect because they highlight the value of having access to data. International comparisons of indicators are also powerful forces for action. Being seen as a blank area on a map (or a blank entry in a table) can often motivate the country concerned to collect the data needed to fulfil the indicator.

Latency, lags and the timeliness of indicators

Not all health effects are felt immediately, even in children. Many diseases (e.g. cancers) have long latencies, in some cases of several years. In these cases, using indicators based on historic exposure data is essential if we want to understand current health effects and trends. How timely an indicator must be thus depends on the degree of latency involved.

Computation. Another important consideration in relation to indicator design is the method of computation. This refers to the process of converting the raw data we use into our indicator. Two crucial factors have to be considered in this context: the choice of metric (the specific form in which we want to express the indicator), and the procedures that can be used to calculate it.

Most indicators can be measured and expressed in many different ways: for example as numbers or counts, as percentages or proportions, as intensities or rates, or as qualitative measures of quality or importance. In each case, we can also choose different statistical measures: for instance, the mean, median, or some measure of extremes (the 95th percentile or maximum). Our choice will greatly affect the message that the indicator conveys. Exactly how we formulate the measure — the denominator we choose, the quality classification we apply, or even the measurement units we apply — will also be crucial.

Computational procedures may also vary. In some cases these may involve little more than bringing the data together under an appropriate form (i.e. in the relevant geographic units and for the time periods of concern). More frequently, however, we may need to link and combine different data — for instance to estimate the number of children living in an area of risk for some disease. In such cases various processes of data transformation and overlay may be necessary. Occasionally, computation may involve the use of complex models or statistical techniques.
In all these cases, three sets of tools are likely to be useful:

- geographic information systems, to enable us to integrate and link spatial data;
- statistical packages to enable us to compute the necessary statistics (and carry out tests for reliability etc); and
- programming environments, in which we can develop any necessary models.

Whatever metrics and methods we adopt, we must always describe them clearly. One reason to do so is so that other people can follow our procedures and produce comparable indicators. This is vital, for even quite small differences in methodology can sometimes produce significant differences in the indicator. Another more mundane reason is that it is all too easy to make mistakes in comparing indicators from different places or at different times if the units of measurement or statistical measures are not clear. But there is yet another reason for computational clarity — namely to allow users and others to verify our calculations, and challenge them if they so wish. We should never be so arrogant as to assume that the information we generate is beyond reproach. By making the data and methods transparent to others we are likely to increase their acceptance, rather than diminish it.

Presentation. We should also not neglect the importance of the methods we use to present the information. We tend to believe what we see. How we display the indicators consequently carries great influence. If we present them in a clear and interesting way, people will tend to pay attention and react; if we bury them in reams of numbers and fine print, few are likely to take heed. In designing indicators, therefore, we need to make an effort to communicate them in a lively and informative way. Many of the principles are self-evident. Graphs and maps will probably be more expressive than tables or text. Colour is more effective than black and white. Interactive materials are more stimulating than static ones. These days, the Web is often a more effective medium than the hard copy document (though better still to use both).
But the way we present indicators can also be influential in another way, for many of the choices we make affect the nature of the message as well as its impact. The class intervals used in graphs or maps, for example, can either emphasize or mask patterns and differences. Scales can likewise be selected manipulatively (e.g. either to stretch

or shrink trends on a graph). Even the choice of colours, symbols and lettering can have important, though often subliminal, effects. Reds are often implicitly read as negative or bad, greens as good. (Red-green combinations are, however, often best avoided because they are the most common form of colour-blindness.) Filled symbols will be seen more readily than open ones; simple fonts (e.g. Arial) will be read more easily (and often seen as more definitive) than more ornate fonts (e.g. Times New Roman). Each of these aspects of design, minor though they may appear to be, merits attention, not just for the sake of clarity and cosmetics, but also to avoid unwanted bias. In addition, we need to recognize that the reader and user of the indicator is often no expert. Help in interpreting the indicator is therefore frequently essential. Probably the best way of achieving this is through a simple and brief commentary. Important elements include: a summary of what the indicator shows, comments on its implications, and some note about possible uncertainties or limitations of the data, and potential pitfalls in interpretation. In this, too, care is needed to minimize bias even if bias can probably never be wholly eliminated. Certainly we should remember that the purpose of indicators is to communicate, and we should thus ensure that they do so. Otherwise our efforts are wasted.

3.4.3 Indicator profiles

If all the aspects of indicator design outlined above are faithfully addressed and recorded, then they should be readily transparent both to those who have to construct the indicators and to those who use them. To ensure that this is the case, detailed metadata, describing each indicator and how it was designed, should always be made available. The information provided should include not only full definitions and details of computation, but also guidance on the data sources used (and, where relevant, possible alternatives), the scale at which the indicator might legitimately be applied (e.g. national, local), and its possible applications.

One way of providing all this technical information is in the form of an indicator profile. In recent years, these have been produced by a number of organizations as part of the process of indicator development (e.g. United Nations 1996, WHO 1999). Table 6 presents an example, designed to reflect the different design issues discussed here. The CD-ROM presents profiles for all the indicators listed in Tables 1-5 above.

Of risks and rates

One of the most common ways of expressing indicators is as rates (e.g. mortality rate or relative risk). Rates, however, can be highly misleading. They tell us how widespread the problem is, but not its magnitude. For example, a relative risk of 20% may sound dramatic but in a population of only 50 people, the problem affects only 10. In contrast, a relative risk of 0.2% represents a large public health problem across a population of millions. By the same token, trends in relative risks or rates must be interpreted with care. The rate may be declining, for example, but if the population is growing faster, then the size of the health burden may be getting bigger.

The same is true when we use standardized mortality or morbidity rates to compare different areas. This may provide a valid basis for comparison if the distribution of age and gender is similar in the areas (or different time periods) concerned. But it can be highly misleading if they differ substantially. For in those cases, what may seem like stark differences in health risks may be no more than a function of underlying differences in population structure.

Table 6. Indicator profile

BRIEF DESCRIPTION OF INDICATOR	
GENERAL CONSIDERATIONS	
Issue	Lists environmental health issues for which the indicator is relevant.
Type of indicator	Specifies type of indicator: exposure (distal or proximal), effect or action; may list several types where indicators can be used and interpreted in different ways.
Rationale	Describes reasoning behind selection of indicator.
Issues in indicator design	Discusses key problems and considerations in designing and developing the indicator: e.g. issues of definition, data availability or data quality, target age range.
SPECIFICATION	
Definition	Gives detailed definition of the indicator.
Terms and concepts	Defines all terms and concepts involved in describing and constructing the indicator.
Data needs	Lists data needed to construct indicator.
Data sources, availability and quality	Outlines potential sources of data, and comments on their quality and characteristics in terms of the indicator. Where appropriate, indicates ways of obtaining data which are not readily available (e.g. through special surveys).
Level of spatial aggregation	Defines basic geographic units or areas for which the indicator should be compiled and presented (e.g. census district, water supply zone, city, country).
Averaging period	Defines time periods or intervals for which the indicator should be compiled and presented (e.g. month, year, decade).
Computation	Specifies the way in which the indicator is computed: i.e. how the data are analyzed/processed to construct the indicator. Where relevant, expresses the computation process mathematically, and defines the terms used.
Units of measurement	Specifies the units of measurement used in presenting the indicator.
Worked example	Presents a simple example, showing how the indicator is computed.
Interpretation	Describes possible applications of the indicator and discusses the ways in which the indicator may be interpreted in these contexts. Shows what inferences can be made from apparent trends or patterns in the indicator. Discusses, in particular, constraints on the interpretation of the indicator, due for example to limitations of the data or complexities in the relationships implied by the indicator.
Variations and alternatives	Presents possible alternatives and modifications to the indicator and suggests proxies that might be used where data are lacking.
Related indicators	Gives examples of similar indicators from other indicator sets (where available).
Useful references	Gives full details of references to published literature relevant to the indicator, including research papers that demonstrate the scientific rationale for the indicator, and examples of the indicator use.

4. CONCLUSIONS

This report has outlined the rationale and background to the set of indicator profiles that is included on the CD-ROM. Whilst acknowledging from the start the urgent need for action to tackle the immense problems of children's environmental health, it has argued that information alone is not enough. Information needs to be relevant and reliable if it is to be effective. And even the best information will only be effective if it is used by people who are open to the messages it tries to convey.

Given this context, indicators can certainly be useful tools for understanding and action. If they are to guide us to make better choices and take more informed action, however, they need to be designed logically, openly and honestly. We need to recognize their limitations and not fool ourselves by believing in them too much. We must be aware that they merely hint at some answers and do not tell us all we need to know. We need to accept that though they may point us in the direction we should travel it is we who have to take the road.

The indicators on the enclosed CD-ROM are therefore only the signpost for our journey; they are nowhere near the end-point. To contribute anything, they must now be allowed to leap off the page and be put to work. First, this means that they must be matched against the needs of those they have to serve – and that is not the user, but the children they are intended to help, globally, nationally, locally. Second, they must be trialled and tested, using the data that are available, so that they can be adapted and improved as necessary to meet specific needs. Then they need to be constructed, implemented and applied. Finally, we must take note of what they tell us, and act accordingly.

All these things need to be done urgently, for while we wait children suffer and die. So the indicators we present here are not an end or an answer, but a beginning and a challenge. The challenge is this: seek, listen and respond, for millions of children are calling.

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6. WEB-BASED DATA SOURCES

Demographic and Health Surveys
http://www.measuredhs.com

UNICEF – Research and Evaluation
http://www.unicef.org/reseval/index.html

UNICEF – Child Survival and Health Statistics
http://childinfo.org/eddb/health.htm

UNEP – Global Environmental Outlook Data Compendium
http://geocompendium.grid.unep.ch/

United Nations – Millennium Indicators Database
http://unstats.un.org/unsd/mi/mi_goals.asp

World Bank - Living Standards Measurement Study
http://www.worldbank.org/html/prdph/lsms/

World Health Organization – A Guide to Statistical Information
http://www.who.int/research/en/

World Resources Institute – The Environmental Information Portal
http://earthtrends.wri.org/

ANNEX: OVERVIEW OF INDICATORS FOR

	CONTEXTS	EXPOSURES
PERINATAL DISEASES	Children aged 0-14 years living in poverty	Famine risk People living in informal settlements Women of childbearing age who are malnourished Women of childbearing age working in unregulated workplaces Births to mothers living in unsafe or hazardous housing
RESPIRATORY DISEASES	Children aged 0-14 years living in poverty	Children aged 0-14 years living in unsafe, unhealthy or hazardous housing Overcrowding Children aged 0-14 years living in proximity to heavily trafficked roads Mean annual exposure of children aged 0-4 years to atmospheric particulate pollution Children aged 0-4 years living in households using biomass fuels or coal as the main source of heating and cooking Children aged 0-14 years living in households in which at least one adult smokes on a regular basis Intrauterine growth retardation in newborn children
DIARRHOEAL DISEASES	Children aged 0-14 years living in poverty	Drinking water supplies failing national microbiological water quality standards People living in informal settlements Children aged 0-14 years living in disaster-affected areas Children aged 0-14 years living in households without basic services for water supply, sanitation and hygiene
INSECT-BORNE DISEASES	Population growth rate in areas endemic for insect-borne diseases	Total area of insect vector habitats Children aged 0-14 years living in households providing suitable conditions for insect-borne disease transmission Children aged 0-14 years living in areas endemic for insect-borne diseases
PHYSICAL INJURIES	Children aged 0-14 years living in poverty	People living in informal settlements Children aged 0-14 years living in disaster-affected areas Children aged 0-14 years living in proximity to heavily trafficked roads Children aged 0-14 years involved in routine employment Children aged 0-14 years living in unsafe, unhealthy or hazardous housing Children aged 0-14 years living in homes lacking access to a piped water supply

CHILDREN'S ENVIRONMENTAL HEALTH

HEALTH OUTCOMES	ACTIONS
Perinatal mortality rate Intrauterine growth retardation in newborn children Congenital malformations requiring surgical correction in children under 1 year of age	Women of childbearing age within one hour's travel of specialist maternity and perinatal care Attributable change in number of households lacking basic services Prevalence of stunting in children aged 0-4 years
Mortality rate for children aged 0-4 years due to acute respiratory illness Morbidity rate for children aged 0-4 years due to acute respiratory illness Prevalence of chronic respiratory illnesses in children aged 0-14 years	Attributable change in tobacco consumption Attributable change in atmospheric pollutant concentrations Attributable change in numbers of households relying on biomass fuels or coal as the main source of heating or cooking
Diarrhoea mortality rate in children aged 0-4 years Diarrhoea morbidity rate in children aged 0-4 years Recurrence rate of outbreaks of diarrhoeal disease among children aged 0-4 years	Attributable change in the number of households lacking basic services Attributable change in the number of food outlets failing food hygiene standards Children aged 0-4 years able to obtain rehydration therapy within 24 hours of need
Mortality rate of children aged 0-4 years due to insect-borne diseases Prevalence of insect-borne diseases in children aged 0-14 years	At-risk children aged 0-14 years covered by effective, integrated vector control and management systems
Mortality rate of children aged 0-14 years due to physical injuries Incidence of physical injuries to children aged 0-14 years requiring treatment	Children aged 0-14 years living within reach of specialist emergency medical services Attributable change in physical injuries to children aged 0-14 years requiring treatment

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