ENVIRONMENTAL HEALTH HAZARD MAPPING FOR AFRICA

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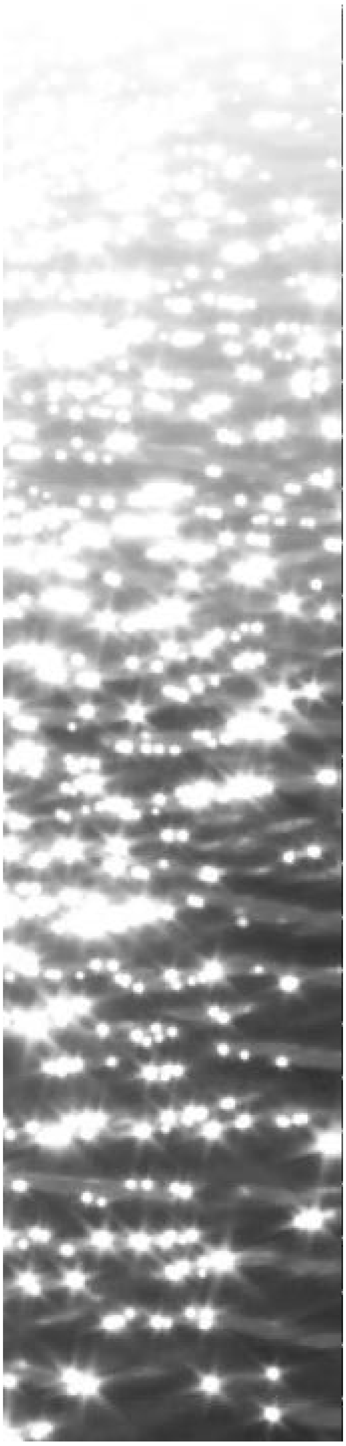


Executive Summary

1. This report presents an assessment and review of *environmental health hazard mapping* in Africa. It seeks to address four key questions:

   i. what is environmental health hazard mapping?
   ii. what can environmental health hazard mapping offer?
   iii. is environmental health hazard mapping feasible in Africa – and what are the constraints?
   iv. what should be done next?

2. The report has been compiled on the basis of:

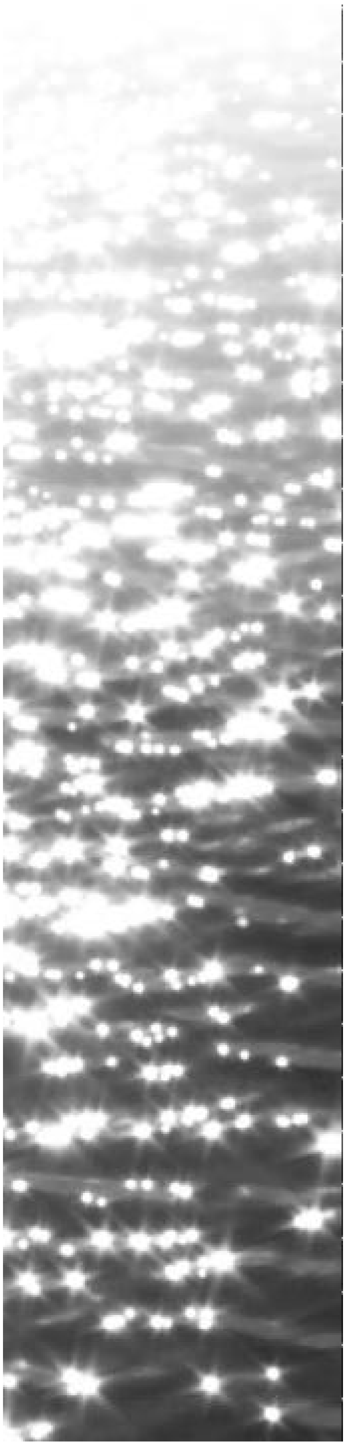
   - discussions and brain-storming with key personnel at WHO-Afro offices in Harare;
   - a literature and web-based survey of existing materials and examples;
   - the specific experience and thought development of the consultant.

3. Environmental health hazard mapping is defined as: *A set of methods for mapping and analysing the distribution, character and magnitude of environmental conditions and processes which might pose significant threats to human health.*

4. As such it focuses on the *causes* of environmental health impacts and the *potential risks* to human health. It thus needs to be distinguished from, but provides a vital precursor to, both risk mapping and health impact mapping.

5. Environmental health hazard mapping is shown to have a wide range of potential applications in Africa (as elsewhere), at the international, national and local level. Key areas of use include:

   - to support and encourage strategic health impact assessment of developments and policies likely to impinge on public health;
   - to provide early warning of environmental health hazards and encourage emergency preparedness;
   - to help inform, involve and empower the public and other key stakeholders in preventing, controlling and managing environmental health hazards;
   - to help prioritise environmental health issues and to target effort and resources where they are most needed and likely to be most effective.



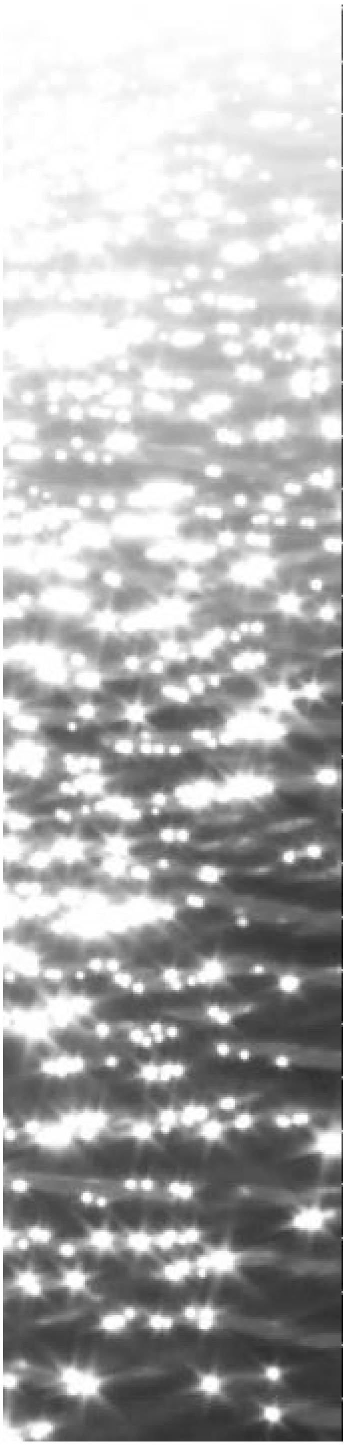
6. Many examples of environmental health hazard mapping already exist. Though many of these are in the western world (especially the USA), these include a number of applications in Africa and other developing regions. They provide valuable lessons both about how to undertake hazard mapping and the potential value of the results. A range of examples are presented in Annex 1 of this report.

7. As these examples show, *geographical information systems* (*GIS*) provide a powerful (and indeed essential) technology for carrying out environmental health hazard mapping and for displaying and communicating the results. Although a range of simple mapping tools are available (some disseminated by WHO), it is argued that the long-term development of environmental health hazard mapping is best served through the use of proprietary GIS.

8. *Indicators* are also essential tools for environmental health hazard mapping. These provide the means of describing and comparing hazards in terms which are relevant to the users of the information. This report argues that good indicators need to be developed and adapted according to the specific needs of the users; as a result, definitive sets of indicators cannot easily be developed. It is more important, therefore, that users of environmental health hazard mapping know how to develop indicators which meet their needs. Annex 2 of this report presents a list of 'indicative' indicators relating to environmental health hazards and provides guidance on how to construct them, and how they might be used. Three types of indicator are proposed: *hazard indicators*, *risk indicators* and *health impact indicators.*

9. The development of environmental health hazard mapping in Africa is limited, in the short-term at least, by a number of problems. These include lack of suitable data, limitations of expertise and technology and financial constraints. This report nevertheless argues that, in the long-run, the benefit-cost ratio of developing environmental health hazard mapping is likely to be positive (or neutral at worst). The main costs of environmental health hazard mapping are likely to relate to data collection: these can, however, be deferred to a considerable extent if hazard mapping is encouraged to grow adventitiously (i.e. in response to local need and resource availability). This report thus proposes that much can be achieved by making the best possible use of the data and other resources which currently exist.

10. Many of the data and much of the experience relevant to environmental health hazards is distributed across different sectors and areas of expertise. Hazard mapping thus requires



a multi-sectoral and multi-disciplinary approach. Such an approach will also enable the costs of mapping to be shared, and the benefits of data linkage to be exploited more effectively. Development of collaboration between the various sectors and departments is vital if environmental health hazard mapping is to be successful.

11. Based on this analysis, the report concludes that environmental health hazard mapping is both feasible and potentially highly valuable in Africa. As well as providing useful information in support of environmental health policies, it will also help to instil a more strategic, forward-looking and information-based approach to decision-making amongst those concerned.

12. The report argues that action should therefore be taken to advance environmental health hazard mapping in Africa. WHO-Afro (in collaboration with other agencies at international, national and local level) has a vital role to play in this respect, and a programme of action is proposed. Important elements of this programme are:

- a campaign of awareness-raising in the member countries (based on real-world examples and demon strations of environmental health hazard mapping), aimed at key decision-makers
- encouragement and support for the sharing of experience and facilities – e.g. by building up expert net works and organising workshops, seminars and study visits
- adoption of a multi-sectoral approach to environmetal health hazard mapping – encouraged by the development of national networks
- support for incremental and adventitious development of environmental health hazard mapping in the member countries – i.e. by encouraging local developments in response to local needs, which can make the best possible use of available data and expertise;
- support for training and long-term capacity-building – e.g. by developing a *manual* on environmental health hazard mapping and be encouraging member countries to develop national environmental health plans.

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1. Introduction

1.1 Aims and purpose of report

This report is designed to assess the potential and practicality of undertaking environmental health hazard mapping in Africa. The aim is to provide guidance on whether environmental health hazard mapping is useful and feasible in the African region, and if so what role it might play and how it might be advanced. In this context, the report addresses four specific sets of questions:

1. What is environmental health hazard mapping?
   - What do the terms mean?
   - What underlying assumptions is it based on?

2. What can environmental health hazard mapping do?
   - For what purposes might it be used?
   - By whom?
   - What added-value can it provide?

3. Is environmental health hazard mapping feasible in the African region?
   - Are the necessary data available?
   - Is the relevant technology available?
   - Is the relevant expertise available?
   - Can the costs be met?

4. How can an environmental health hazard mapping system or programme be developed?
   - What are the key issues which need to be addressed?
   - Who should be responsible?
   - Who should pay?

Based on this discussion, the report then makes recommendations for further action by WHO-Afro and its member countries to advance the development and implementation of environmental health hazard mapping in the region.

1.2 What is environmental health mapping?

1.2.1 Definitions

The concept of environmental health hazard mapping is relatively new. The terms environmental health, hazard and mapping are also open to different interpretations. From the start, therefore, it is important to clarify the meaning of the key terms employed.

Environmental health may be more or less narrowly defined. In its strictest definition, it is often taken to refer exclusively to the effects of the 'natural' or ambient environment on health; more broadly, it or may be taken also to include the social and cultural environment. This report adopts the middle ground. Environmental health is defined as those aspects of the living environment of humans, insofar as these may affect health. As such, it focuses on the tangible (physical, chemical, organic) environment, including both the ambient and indoor environment, but it excludes social and cultural factors which are not expressed in some way through the tangible world. This definition of environmental health allows for the inclusion of the occupational environment – in many cases one of the most important determinants of health. Whether or not occupational health is encompassed in practice, however, often depends on the administrative structure of the organisations involved: for example, whether there is an independent ministry of labour which has responsibilities for workplace conditions and occupational safety or whether occupational issues are covered by the Ministry of Health.

Hazard refers to those factors or conditions which have the potential to pose a threat to human wellbeing and, more specifically in the context of this study, to health. As such, it is important to differentiate between hazards and risks, and to understand the relationship of both these to human health. *Hazards* represent the presence of an environmental risk factor: *risk* only occurs if humans are in some way exposed to this factor at levels which might affect their health. A health effect occurs only if individuals within the exposed population are susceptible to the effects of the hazard, and if they accumulate sufficient exposures to experience an effect (Figure 1).

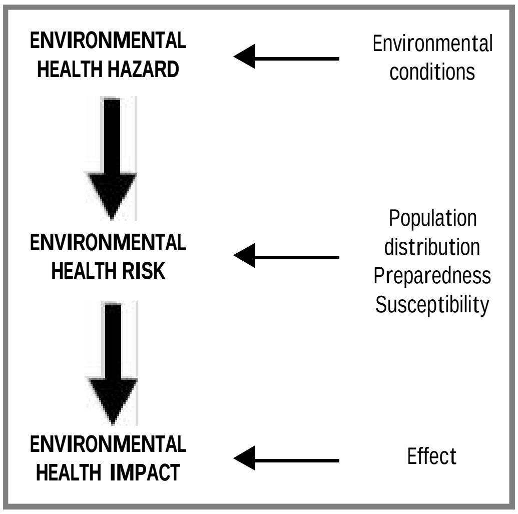


Figure 1.
Relationships between environmental health hazard, environmental health risk and environmental health impact

Environmental health hazards take many forms, and may be classified in many different ways (e.g. on the basis of the substance or process involved, the medium or environment of exposure, or the health effect). Possibly one of the most effective ways of classifying them (and the one loosely adopted here) is as shown in Table 1. It needs to be recognised, however, that the most effective classification is the one which best meets the needs of the specific purpose: no classification is likely to be universally optimal.

Table 1. A classification of environmental health hazards

Category	Examples of hazards	Health risks
Natural hazards	Volcanic activity	Includes effects of direct injury by volcanic debris, lava etc, inhalation of gas/dust and indirect effects of famine etc
	Avalanches	Primarily direct injuries from avalanches; includes rock and snow avalanches
	Earthquakes	Includes direct injury from effects of earth tremors (e.g. building collapse), and indirect effects (e.g. of flooding, tsunamis, epidemics and famine)
	Flooding/storms	Includes direct effects of drowning and injury by floods/ storms, and indirect effects of water contamination, famine and epidemics
	Drought	Primarily health effects due to lack of potable water and famine
	Hurricanes/wind	Primarily direct effects of injury (e.g. by collapsing buildings), but may also include longer-term effects of famine and contamination/loss of water supplies
	Lightning strikes	Direct injury
	Soil erosion/ desertification	Primarily famine and poor diet due to effects on food supply
	UV radiation	Skin cancer
Atmospheric hazards	Outdoor air pollution	Wide range of respiratory, pulmonary and cardio-vascular illnesses and cancers
Water-related hazards	Surface water pollution	Primarily diarrhoeal and gastro-intestinal diseases, but may also include chemical poisoning
	Drinking water contamination	Gastro-intestinal and urinary diseases; rarely chemical poisoning
Food-borne hazards	Biological contamination	Wide range of diseases of the digestive system
	Chemical contamination	Diseases of the digestive and urinary systems; rarely chemical poisoning
Vector-borne hazards	Water-related vectors Animal-related vectors	Infectious and parasitic diseases Infectious and parasitic diseases
Domestic hazards	Indoor air pollution	Wide range of respiratory, pulmonary and cardi-vascular illnesses and cancers
	Domestic accidents Suicide	Physical injury and poisonings Suicide through use of household chemicals, drugs, instruments

Category	Examples of hazards	Health risks
	Sanitation	Infectious and parasitic diseases; diseases of the digestive and urinary system
	Waste handling	Infectious and parasitic diseases; diseases of the digestive and urinary system
Occupational hazards	Industrial pollutants	Wide range of respiratory, pulmonary and cardi-vascular illnesses and cancers; chemical poisoning
	Occupational accidents	Acute physical injury (e.g. by fire, explosions, accidents with equipment) and chronic injuries (e.g. repetitive strain injury, back-pain)
Infrastructural hazards	Traffic accidents	Physical injury (to vehicle occupants and pedestrians/ cyclists)
	Industrial accidents	Primarily acute physical injury (e.g. by fire, explosions), chemical poisoning and respiratory effects
	Contaminated land	Mainly diseases of digestive and urinary system
Social conflicts	War	Almost all forms of health effect
	Domestic violence	Physical injury, stress-related illnesses

Mapping refers to more than simply the production of maps. The map is merely the end product of an often lengthy and complex analytical process (Figure 2) – a model of reality. How well it expresses this reality depends upon the decisions made, and the methods used, during this mapping process. Figure 3 presents an example. This shows the distribution of malaria risk in southern Africa, based on two methods: modelling of climatic suitability (Figure 3a) and a compilation of data from different sources (Figure 3b). While the maps depict broadly similar patterns, differences in methodology create discrepancies of detail. The map is thus sensitive to the assumptions made in the modelling. Similar problems occur in mapping urban air pollution on the basis of data from monitoring stations. In this case, to produce a map of the pollution surface, a process of 'interpolation' has to be carried out, by which estimates are made of pollution levels for locations between the monitoring stations. Again, many different assumptions need to be made in this process, and many different techniques of interpolation can be used; each is likely to produce a different estimate of the pollution surface. The final map is thus not a definitive representation of the pollution surface; it is simply one of many different estimations of the pollution pattern which might have been produced.

Maps may take many different forms. In portraying environmental health hazards, maps will often be thematic – i.e. they will show the distribution of one or more features or themes, graded or classified according to their type or degree of hazard. Many different methods may be used for this purpose, for example:

- Dot maps, to show the location of specific hazards
- Proportional symbol maps, in which the size or colour of the symbol is varied to reflect the difference in the scale or magnitude of the hazard
- Contour maps, in which the hazard is represented as a continuous surface, defined by contours linking places of equal hazardousness
- Choropleth maps, in which areas are shaded or coloured according to their degree of hazardousness

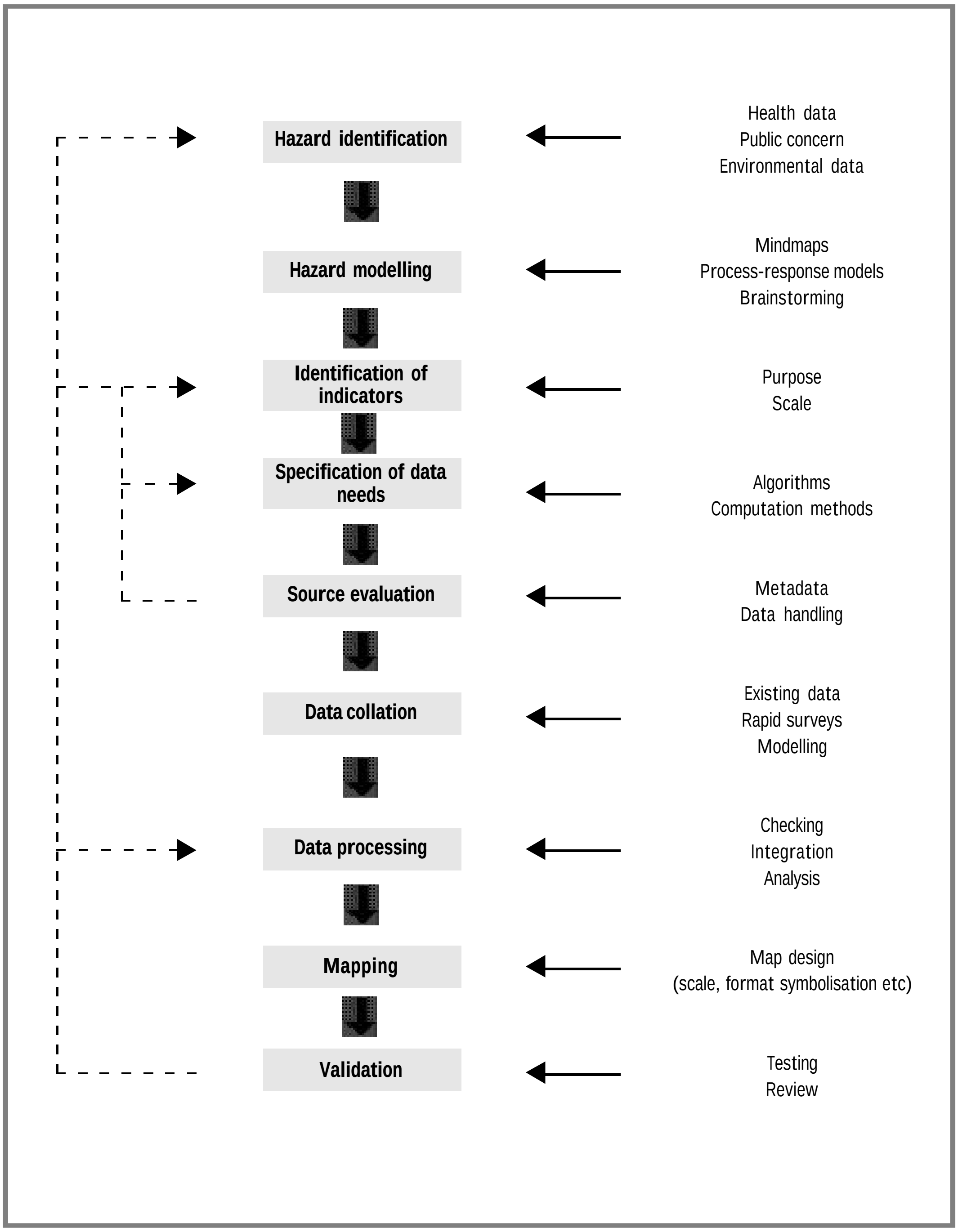
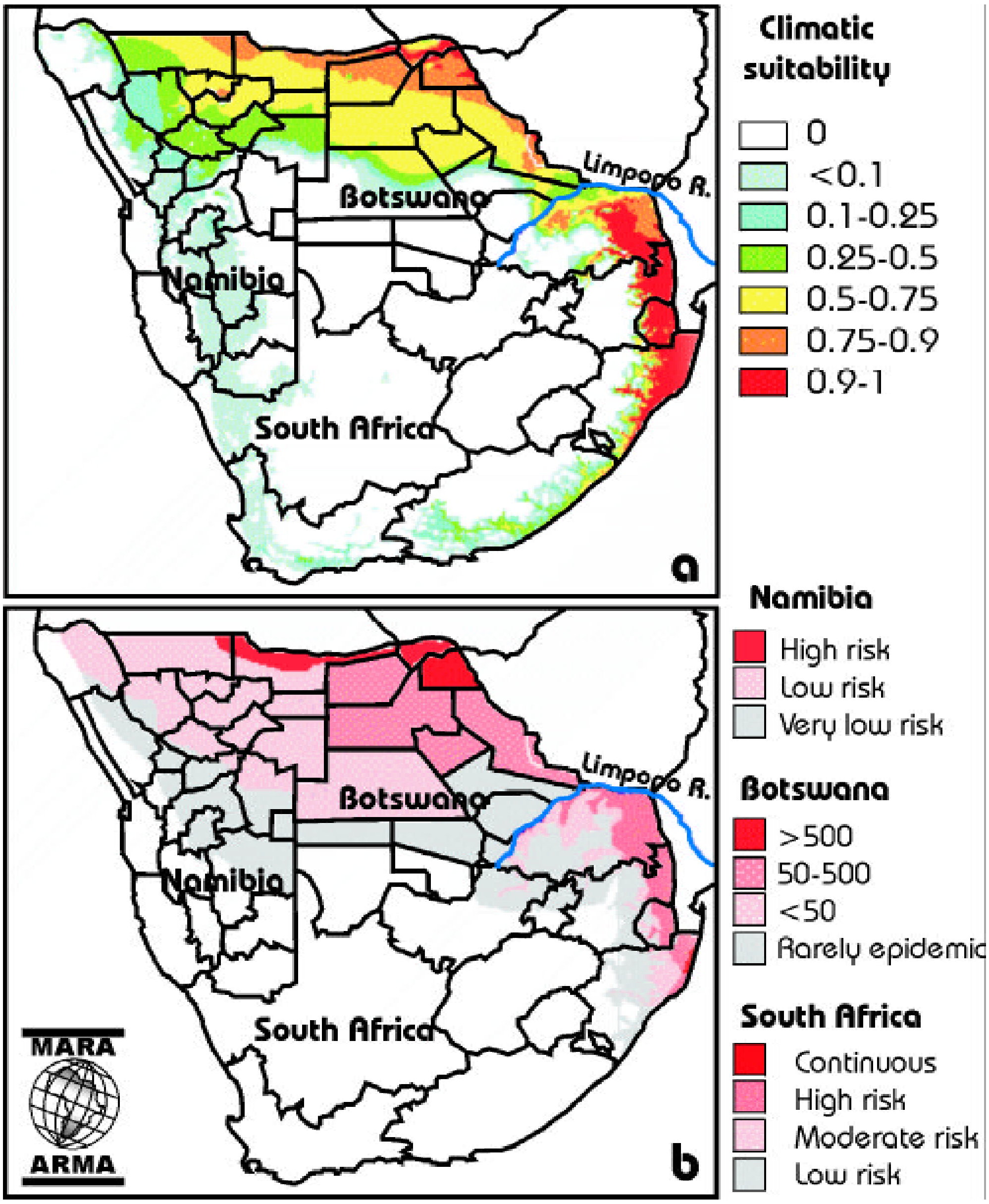


Figure 2. The steps in environmental health hazard assessment



a. Malaria risk map based on an analysis of climatic suitability

b. Malaria risk map based on a combination of: expert opinion (Namibia), annual confirmed number of malria cases, 1982-94 (Botswana) and a risk map compiled by the South Africa Department of Health (S. Africa)

Source: MARA (1998)

Figure 3. Malaria risk maps for southern Africa

In each case, the character of the finished map depends on the decisions and choices made as part of map design. These include the selection of the features to be mapped; scaling or classification of these features; choice of symbolisation and colour; choice of map scale; choice of map projection; choice of map annotation and layout. Each of these may affect the message which the map conveys, albeit often without the user being aware. The use of large symbols to represent a village, for example, implies that the settlement is large. The choice of class intervals on a choropleth map may greatly alter the apparent geographic pattern shown by the data. The colours selected for mapping may carry hidden messages: red is often associated with poor environmental conditions, green (or blue in the case of water features) with good environmental conditions. Maps are therefore not neutral, and they must be designed and interpreted with care.

It also needs to be appreciated that, although the map is one output from the mapping process, it is not necessarily the only one. Mapping also provides a wide range of data, which can be presented in other forms: for example, as tables, graphs, textual commentaries or images.

Put together, therefore, these definitions suggest that environmental health hazard mapping can be specified as follows:

> *A set of methods for mapping and analysing the distribution, character and magnitude of environmental conditions and processes which might pose significant threats to human health.*

It is this definition which will be assumed throughout the rest of this report.

1.2.2 Examples

Many examples of environmental health hazard mapping, which match the definition given above, already exist in different parts of the world. Indeed, in many countries hazard mapping is an integral part of national or regional planning and health protection policies. Mapping is probably best developed in relation to natural hazards (especially floods, seismic risks and drought) but increasing effort is being given to mapping other hazards such as air pollution, water quality and vector-borne disease hazards. A number of examples are listed in Table 2. More detailed case studies are presented in Annex 1 of this report.

1.3 Conceptual issues

The development and use of environmental health hazard mapping poses a number of important conceptual issues. How these are resolved is likely to affect fundamentally the way in which hazard mapping is carried out, and the extent of its uptake and success.

1.3.1 Environmental hazard mapping, environmental risk mapping or environmental health mapping

The relationship between environment and health can be seen as a chain, comprising three distinct links: the environment, the population, and health (Figure 1). Considered from the viewpoint of environment as hazard, the chain can be characterised as follows. Certain environmental conditions create hazards. If people come into contact with, and are thus exposed to, these hazards, then health risks occur. If individuals within the exposed population accumulate exposures which exceed their resistance or tolerance then health effects occur.

This concept of the environment-health chain allows three different approaches to mapping to be defined: environmental hazard mapping, environmental risk mapping and environmental health mapping.
Environmental hazard mapping involves mapping of the distribution and magnitude of environmental hazards with the capacity to affect health, without consideration of the population. This is based solely on information on the environment.

Table 2. Examples of environmental health hazard mapping

Country/region	Description
Africa	MARA is mapping the distribution of malarial mosquitoes, breeding season characteristics (start-date, end-date, length) and climatic suitability to support management programmes.
Africa	USAID routinely compiles maps of rainfall, drought hazards and food security to help monitor the need for aid and to focus attention on at-risk areas
Alaska	Alaska Community Action on Toxics have developed a series of hazard maps on toxic sites, sources and releases in the state, as a basis for raising public awareness and lobbying governments and industry.
Asia	The Asian Urban Disaster Mitigation Program (AUDMP) is developing environmental health hazard maps for a range of hazards in partner countries: Philippines (Floods, Volcanoes, and Earthquakes); Indonesia (Earthquakes); India (Technological and Industrial Hazards); Sri Lanka (Multi-hazard); Lao PDR (Fires and related Urban Hazards); Nepal (Earthquakes); and Cambodia (Floods).
Australia	Flood maps are produced for urban areas, which define zones liable to flooding. Within these areas, flood warning systems are established, strict planning guidelines are enforced (to help protect buildings), and special flood management schemes may be implemented (e.g. stormwater control). These maps are also used by insurance companies to adjust premiums.
California	Coastal areas are mapped in terms of their flood hazards; these maps are used as planning tools, and strict controls on development and land management are enforced in flood-prone areas.
Central America	The Onchocerciasis Elimination Program for the Americas (OEPA) is mapping risks of river blindness in six countries in Central America (Brazil, Colombia, Equador, Guatemala, Mexico and Venezuela) as a basis for planning and monitoring intervention.
European Alps (and other ski-resort areas)	Snow avalanche maps are compiled and maintained which provide warnings to visitors about safe ski-routes.
Guatemala	Researchers at Michigan University have compiled a volcanic risk map for Santa Maria, as a basis for identifying the population at risk and potential economic costs.
UK	The UK National Air Quality Strategy requires local authorities to identify and map areas which exceed national air quality targets, as a basis for establishing Air Quality Management Zones. These areas must be managed in order to reduce air pollution to acceptable levels in order to safeguard public health.
USA	USGS compiles seismic maps of the USA at national and regional level, showing earthquake and other risks. Maps are used to inform planning and to enforce building protection regulations.
USA	The Federal Emergency Mapping Agency (FEMA) compiles flood maps to assess new projects, to give guidance on building protection and to raise public awareness about the needs for insurance.

Environmental risk mapping involves mapping of the *potential* risk to human health, either by estimating the numbers of people exposed to the environmental hazards, or (if dose-response relationships can be established) by estimating the likely health burden. This is based on information both on the environmental hazard and on the distribution (and possibly susceptibility) of the population, or on direct estimates of population exposure. It may also need to take account of potential confounding by other, non-environmental factors. One of the most important is the degree of preparedness of the exposed population to avoid, or mitigate, the effects of the hazard. For example, the death-toll due to earthquakes varies substantially between different countries, depending upon the extent to which buildings have been designed to be earthquake resistant. Similarly, the effects of exposures to hazardous chemicals in the home varies depending on the extent to which safe packaging, clear labelling and controls on sales have been enforced. Risk mapping should therefore take account of these infrastructural factors. Differences in individual susceptibility (e.g. related to general health status, age, genetic characteristics) may also be important.

Environmental health mapping comprises mapping the actual health outcome which can be attributed to exposures to the environmental hazards of concern. This is based either on health data alone (e.g. where sentinel diseases can be identified which are attributable to specific environmental exposures), or by linkage of health data to information on the environmental hazards (with allowance, where relevant, for effects of confounding).

Each of these approaches has specific advantages and disadvantages, and each provides different information (Table 3). Each thus supports different types of decision. Environmental health hazard mapping focuses attention on the environment *per se*, and supports an essentially precautionary approach to policy and intervention. Action is implied wherever hazards occur – either by trying to control the hazard itself, or by encouraging hazard avoidance (e.g. by moving people out of the hazard area, or by controlling immigration and settlement in the area). Environmental risk mapping focuses attention on the exposed population. It is likely to target areas where large numbers of people are considered to be at risk. Action is therefore likely to be less precautionary, in that problems will be highlighted only once exposures are seen to occur. Environmental health mapping highlights the effects of exposures on health. Though it can be prospective to some extent (e.g. by looking for early signs of health effects) it is essentially a *post hoc* approach.

Which of these (or which combination of these) is most appropriate in any situation needs to be determined. The decision is likely to depend on a number of considerations, including:

- who the main users are and what responsibilities they have
- what the issues of concern are and the opportunities for intervention
- the availability of relevant data and assessment methods

In general, however, it is evident that environmental health hazard mapping has two specific factors in its favour: it provides a prospective and precautionary approach to health protection; and it is – for many applications – an essential component of other, more specific forms of health risk assessment.

Table 3. Advantages and disadvantages of different approaches to mapping

	Advantages	Disadvantages
Environmental health hazard mapping	• prospective: shows potential risks to health before they occur • uses data only on the environment – less data demanding	• may not translate into a real health risk, if people are not exposed
Environmental risk mapping	• prospective: shows potential risks to health • shows risk to exposed population	• requires knowledge of dose-response relationship if potential health burden is to be assessed • requires detailed knowledge of exposures and preparedness/ susceptibility of population – reliable data often unavailable
Environmental health mapping	• shows actual health outcome – targets action at where problems actually occur • allows for differences in susceptibility and response	• retrospective: shows effects only after they have happened

One aspect specifically relating to environmental health hazard mapping does need to be recognised. This is that the term implies that the environment is being considered only with regard to its negative and harmful effects on health. This may be unnecessarily limiting. Exposures to environmental hazards can certainly cause harm to health; but the environment is also vital for life and can help to sustain and improve human health. By focusing on hazards, therefore, environmental health hazard mapping gives only a partial picture of the relationship between environment and health. In the African region, where much of the emphasis of environmental health policy is targeted at reducing or resolving health problems, this focus may make sense. Nevertheless, the distinction between the positive and negative effects of the environment is not always tenable. Indeed in many cases the difference is purely circumstantial: some people may be beneficiaries of specific environmental conditions, others will be losers. For example, floods which destroy buildings and injure or kill people may also help to spread silt on farmland and thus increase crop yields and save or improve the lives of others. Road traffic, which causes accidents and injury to many, enhances the lives of many others. Environmental hazards and environmental benefits, therefore, are often two sides of the same coin. As noted, the distinction may also be unnecessary. Most of the methods of environmental health hazard mapping considered in this report can equally and easily be used to map and analyse positive environmental effects.

1.3.2 Dealing with multi-causality and confounding

By the same token, the effects of the environment on health are not singular. Many different environmental factors may combine (often in complex, non-additive ways) to influence health. The relationship between environment and health is therefore multi-causal. The effects of any environmental hazard on health may equally be modulated by a wide range of other, non-environmental factors. Population distribution is clearly one important factor: hazards only become health effects when people are exposed; the magnitude of any effect across the population (i.e. the total number of people affected, or the ‘attributable risk‘) depends to a large extent on how many people come into contact with the hazard. Superimposed on these effects, however, are a range of other factors, including variations in the genetic characteristics of the population, lifestyle and social/cultural patterns, each of which might mask or amplify apparent relationships and lead to variations in health outcome. In interpreting environmental health hazard maps, it can be misleading, and ultimately dangerous, to ignore these complexities, for there is rarely a simple or direct relationship between environmental hazards, risk and health effects. Environmental health hazard maps thus need to be interpreted with care. Often, they only make real sense if used in conjunction with other information – for example on population distribution, social conditions and health outcome.

1.3.3 Acute versus chronic hazards

Environmental health hazards can broadly but conveniently be classified into two types: acute and chronic hazards. Acute hazards are essentially episodic in occurrence and result in more-or-less immediate health effects. Examples include most forms of accident (e.g. industrial, occupational, domestic, traffic), many natural hazards (e.g. avalanches, earthquakes, floods, storms), epidemics and short-duration, high intensity pollution events. Chronic hazards operate more slowly, and have more delayed health effects which arise because of the repeated or continuous, low-level exposure of individuals to the hazard.

The distinction between these two types of hazard is important for a number of reasons. The first relates to the nature of the relationship with health effects. In the case of acute hazards, the effects are readily attributable to the hazard concerned. This makes it relatively easy to quantify these hazards in terms of the impacts on health. The relationship between chronic hazards and health, in contrast, is often far less apparent and heavily confounded. For these reasons, it is more difficult to assess these hazards in terms of their health outcome.

Systems for dealing with these two types of hazard also vary to a great extent. Acute hazards often occur at the proportion of disasters – i.e. affecting large numbers of people through a single event. Most acute hazards are also somewhat unpredictable. Emergency response is thus an essential means of coping with these hazards. Effective emergency response nevertheless requires planning: for example, the establishment of suitably trained and equipped rapid response teams. Many acute hazards can also be avoided to some extent: for example, by deterring development and settlement in high-risk areas, by incorporating appropriate safety features into buildings etc, or by establishing early warning systems and evacuation procedures.

The slow pace, greater predictability, and less dramatic impacts of chronic hazards, conversely, allow more time for mitigation and treatment and rarely invoke the need for emergency action. (One exception to this, perhaps, occurs where the hazards go unnoticed until large numbers of people are, or might potentially be, affected, as with HIV-Aids or BSE/Creutzfeldt-Jacob Disease.) They also make it more difficult to justify the adoption of major prevention strategies. This is not to say, however, that these hazards might not be equally, or even more, important in terms of their health effects. Indeed, although the relative risk of such hazards is often low, the attributable risk (i.e. the percentage of people who might be affected) may be considerable, simply because large numbers of people may be exposed. As this implies, however, the need for – and role of – environmental health hazard planning tends to differ between these two types of hazard.

2. What can environmental health hazard mapping do?

2.1 The need for environmental health hazard mapping

The need for environmental health hazard mapping – like other forms of information – may in many ways seem self-evident. As the previous section has suggested, however, this need is not universally accepted, and even less universally addressed. Moreover, how environmental health hazard mapping is developed and used depends upon the specific purposes for which it is intended. It is therefore important to review in some detail the case in favour of environmental health hazard mapping, and to specify clearly the benefits that mapping can bring.

The foundation of this case is that environmental hazards pose major threats to human health. In the African region, certainly, these threats are real. They derive not only from natural hazards (e.g. floods, drought, vector-borne diseases), but also the human-induced effects of pollution and industrial and traffic accidents. In many areas these risks are also increasing. On the one hand, environmental conditions are deteriorating: for example, because of damage by pollution, vegetation destruction and soil erosion, and human impacts upon climate. On the other hand, more people are becoming exposed to these hazards, both because population levels are rising and because of increased migration into cities (and especially into informal urban settlements) where levels of pollution are greater and the risks of contact with vector-borne diseases may be higher. At the same time, rising populations and consumption have acted to deplete the available resource stock and led to serious shortages of vital resources, especially water, in many parts of the world.

Action to tackle the problems of environmental hazards is nevertheless costly, and inappropriate action is at best a waste of valuable resources. Action also takes time, so wrong actions prolong unnecessarily the suffering of those involved. At worst, inappropriate action can actually make the situation worse. We cannot afford to take action lightly, therefore, but must ensure that as far as possible we take the right action, at the right time and in the right place. To achieve this, action must be based on good information, rather than prejudice or hunch.

The need for information to underpin actions on health is now widely accepted. It has been emphasised, for example, by Agenda 21 of the United Nations Conference on Environment and Development, adopted in 1992, by the Helsinki Declaration of WHO in 1994 and by the Interministerial Conference on Environment and Health in London, in 1999. In Africa this need has been further highlighted by the Africa2000 initiative, which argues for improved sharing and co-ordination of information to help improve planning and decision-making, and better communication between the many different parties involved, in order to encourage co-operation and concerted action.

In the light of this growing information need, many different tools and systems have been developed, aimed at improving both the availability of information and its use by decision-makers. Examples include:

- the development of National Environmental Health Action Plans as a framework for action to improve environmental health (WHO 1994, Briggs *et al.* 1999)
- the development and use of indicators in support of health-related programmes (e.g. the Health for All Programme), and to help guide policy development and monitor trends in the environment and health at local, national and international levels (WHO 1996, Corvalan *et al.* 2000);
- the requirement for environmental impact assessment (EIA), strategic environmental assessment (SEA) and, to a lesser but now increasing extent, health impact assessment (HIA) in evaluating policies, programmes, plans and projects (e.g. PAHO 1999).

Hazard identification and assessment is one further weapon to add to this armoury. As WHO (1995) stated, in arguing the case for a more integrated approach to health and environment:

"Efficient environmental health programmes depend on convenient access to information about a large variety of hazards, ranging from biological hazards in food and water, to chemical hazards such as pesticides, and the different physical hazards."

More specifically, environmental health hazard mapping can provide information on the spatial distribution and character of these hazards. This type of information is important for a number of reasons:

- environmental health hazards are themselves geographically expressed; they vary from one place to another;
- People are geographically distributed; whether people are exposed to these hazards, and to what extent, thus depends on the extent to which the hazard and the population occur together or are separated in space (i.e whether they show spatial covariation);
- many of the actions that might be taken to control or mitigate environmental health risks need to be targetted at specific locations or areas, because resources might not be available to intervene everywhere, and because administrative responsibilities and authority is often geographically limited.

If effective decisions are to be made, therefore, information is needed on *where* environmental health hazards are, *how severe* they are, and *who is exposed*. Providing this information is the role of environmental health hazard mapping.

2.2 The role of environmental health hazard mapping

2.2.1 Users and uses

As the preceding discussion has indicated, environmental health hazard mapping is essentially action-oriented. Its purpose is to inform decision-making. It can do so in many different ways, for example by:

- identifying where environmental hazards are most severe ('hazard hotspots') and populations at risk;
- showing how environmental health hazards have changed over time (e.g. in response to policy intervention or natural changes in the environment);
- helping to explore and understand associations between human activity and environmental health hazards, or between environmental hazards and health outcome.

Decisions affecting environmental health are, of course, not necessarily deliberately targetted at environmental health. Many of the decisions of consequence are taken for other motives (e.g. environmental, economic, social or business purposes): impacts upon environmental health are purely incidental or accidental. For this reason – but also because environmental health in some way is the concern of almost everyone – relevant decisions are taken by many different organisations, agencies and individuals, at many different levels. For example:

- at the international level by international agencies and inter-governmental organisations (e.g. WHO, UNEP, PAHO, the EU) and by international companies;
- at the national level by state governments, public agencies, private companies and the national media
- at the local level, by local authorities, health authorities, landowners, businesses, educational institutions and the local media;
- at the personal level by individual members of the public acting on their own behalf or that of their family.

Each of these many different stakeholders, at each of these levels, requires information on environmental health. Each, therefore, might use the results of environmental health hazard mapping. Nevertheless, the interests and needs of these different stakeholders are not the same. Information on environmental health hazards thus serves different purposes for different users. Some of the possible uses of environmental health hazard mapping for key user groups are listed in Table 4. More specific examples of how it might be used, in different situations, are given in the case studies (Annex 1).

The needs of these different users are, however, not wholly independent. Most can benefit from collaboration, and from sharing of information and experience. Indeed, more integrated approaches to environmental health management – based upon collaboration between the various stakeholders – will almost invariably improve its effectiveness. One of the potential advantages of environmental health hazard mapping is that it can help to provide explicit information which can be seen, discussed and used by all those concerned in a more concerted way. In the process, it can also help to achieve consensus about what the real issues are, and how best to tackle them.

WHO-Afro clearly has a particularly important role in this respect, for it has the lead responsibility to support member countries in developing effective strategies for protecting environmental health. WHO-Afro is thus likely to be one of the main users of environmental health hazard mapping, for example:

1. to raise awareness in the member countries about environmental health hazards and the need for action to address them, e.g. by –
   - providing an early warning of potential hazards and health risks
   - compiling broad-scale atlases of environmental health hazards

2. to help build capacity in the member countries to monitor their own environment, as a basis for local action, e.g. by –
   - training national and local staff in hazard mapping and risk assessment
   - providing guidelines and methodologies for environmental health hazard mapping
   - developing networks of experts who can provide mutual assistance

2.2.2 Fitness for purpose

As Table 4 shows, environmental health mapping can serve a wide range of specific purposes. Meeting these different needs nevertheless requires different types of information, analysed and presented in different ways. Environmental health hazard mapping is thus not one technique but many. The techniques of mapping used to investigate or represent environmental health hazards at the international scale are unlikely to be effective at the regional or local scale. The methods used to raise public awareness about environmental health hazards are not the same as those needed to explore associations between environmental hazards and health. Different methods of environmental health hazard mapping may therefore need to be applied in different situations.

The notion of customising hazard mapping to the needs of the user is an important one. It emphasises the need for mapping to be fitted to the purpose for which it is to be used. If this is not the case, mapping is unlikely to be effective. At best, it may simply result in the collection of large amounts of expensive data which are never used. At worst, it may impose a major burden on the countries and local agencies, and may divert effort and resources away from more important activities.

2.2.3 Attitudes to information

Effective hazard management needs more than a methodology to assess and map hazards; it requires that this information then be used to help make decisions. This implies the existence of an 'information culture' – i.e. acceptance of the notion that information can, and does, contribute to improved decision-making. This essentially rationalist model of decision-making is far from universally valid. In many administrative cultures, information may be regarded not as a source of assistance and wisdom, but as a potential threat to the power and status of the

Table 4. Potential uses of environmental health hazard mapping

User group	Key uses and applications
International agencies, inter-governmental	• to prioritise environmental health issues • to target international effort where it is most needed (‘hazard hotspots’) • to help establish standards and targets for environmental health protection • to provide early warning of environmental health risks and encourage organisations preparedness • to raise international awareness about environmental health hazards • to encourage co-operation between countries and agencies and different sectors • to help promote strategic thinking and health planning at the national level • to help build national capacity for preventive and strategic health protection
National policy-makers	• to prioritise environmental health issues • to target national action at where it is most needed (‘hazard hotspots’) • to help formulate effective environmental health strategies • to help assess the health effects of policies and programmes (strategic environmental health assessment) • to encourage more strategic ways of thinking within national/regional agencies • to help establish standards and targets for environmental health protection • to help integrate environmental health issues into other policies/strategies • to monitor the effects of policies on environmental health hazards • to provide an early warning of environmental health risks and encourage emergency preparedness
Local/city authorities, health authorities, health professionals	• to prioritise environmental health issues • to target action at where it is most needed (‘hazard hotspots’) • to help formulate environmental health policies/strategies • to help assess the potential health effects of programmes, plans and projects (environmental health impact assessment) • to help integrate environmental health issues into other policies/strategies • to monitor the effects of policies on environmental health hazards • to help compete for resources • to provide an early warning of environmental health risks and encourage emergency preparedness • to help identify likely diagnoses in cases of uncertainty • to help investigate associations between environmental hazards and human health • to raise public awareness about environmental health hazards
Business, industry	• to raise awareness about environmental health hazards which need to be considered in business plans/strategies • to highlight possible liabilities and insurance risks • to incorporate environmental health issues into project appraisal and impact assessments
Individual members of the public	• to raise awareness about environmental health issues • to help inform personal strategies to avoid/reduce exposures to environmental health hazards • to empower the public • to help the public monitor the activities of national/local policies

decision-makers and a constraint on their freedom. In these cases, information may be deliberately hoarded or suppressed. Even in societies which ostensibly accept the need for information, much of the available information may be ignored or remain unused. The causes may be many. They typically include:

- lack of knowledge about the existence of the information (e.g. due to poor communication between scientists and decision-makers);
- limitations of expertise amongst decision-makers (e.g. in terms of their ability to read or interpret maps);
- limitations of time, money or other resources, which may impair their opportunities to access or use the information.

Often, also, information is used not so much to help guide decisions, but to justify and rationalise decisions after they have been made. Whether environmental health hazard mapping is useful, therefore, depends on the prevailing attitudes to information in general – and to maps in particular – of those who make decisions.

Without an 'information culture', and as part of that a forward looking and strategic way of thinking, environmental health hazard mapping is likely to have little practical effect. As noted in section 2.2.2, it may then simply lead to the collection of data which are never used, and divert rather than support practical efforts to protect health. On the other hand, environmental health hazard mapping can also be a force for good in this respect. Nothing teaches like example, and evidence of how hazard mapping can help to solve environmental health problems can be persuasive in making those concerned think more strategically. Such changes can reach far beyond the specific problems for which hazard mapping might be used. One of the most long-lasting and valuable benefits of establishing methods for environmental health hazard mapping, therefore, is likely to be its contribution to changing the way people think about health planning and protection.

3. Environmental health hazard mapping for Africa

In order to undertake environmental health hazard mapping in Africa, a number of preconditions need to exist:

1. environmental health hazards worthy of mapping need to be defined;
2. for each of these, indicators need to be identified, which might form a basis for hazard assessment and mapping;
3. the data needed to construct these indicators need to be specified, sourced and collected;
4. appropriate mapping methods, technologies and expertise need to be established.

This section examines each of these requirements, and assesses the capacity to meet them in Africa.

3.1 Environmental health issues in Africa

A wide range of environmental health hazards beset the African continent. Attempts to address many of these problems would clearly benefit from environmental health hazard mapping. As noted in the previous section, mapping would be of value not only to international agencies, such as WHO, but more fundamentally to national and local governments, to environmental health professionals, and to the public and many others with a stake in environmental health. The need for environmental health mapping is therefore beyond dispute.

Compiling a definitive list of environmental health issues is nevertheless not easy. Africa is environmentally, as well as culturally and politically diverse: different issues therefore assume priority in different areas, and the capacity to tackle them varies likewise. The priorities for environmental health hazard mapping therefore need to be identified locally. Prioritising environmental health problems is also not easy (see, for example, Victorin *et al.* 1999). It involves trading off and balancing a number of different criteria, including:

- the number of people at risk
- the severity of the health effects
- the urgency (i.e. timescale) of the effects
- the level of public concern
- the feasibility of effective control
- the costs of intervention

A number of general environmental health issues can, however, be delimited, comprising problems which either affect large areas of the continent, or are locally severe in that they pose major risks to significant numbers of people. These are listed, with comment, in Table 5. It must be stressed that this list is not intended to be definitive or limiting: it merely represents an indicative set of environmental health hazards which are of concern in Africa, and which might provide a framework for mapping, at least at the international level.

Table 5. Environmental health hazards in Africa

Category	Hazard	Comment
Land/ climate-related hazards	Volcanic activity	Eastern Africa – Rift Valley area
	Earthquakes	Limited mainly to Rift Valley and Mediterranean fringe
	Avalanches	Mainly in mountain areas where steep slopes have been settled (e.g. Madagascar)
	Flooding/storms	Widespread in both lowland coastal and inland areas, especially in Tropics and monsoon areas
	Drought	Widespread problem throughout semi-arid and arid areas of Africa; possibly becoming worse as a result of global climate change
	Hurricanes/wind	Widespread problem in Tropics
	Soil erosion/ desertification	Widespread in arid/semi-arid Africa; encouraged by over-grazing and deforestation; may also be worsening due to global climate change
	UV radiation	Increasing problem due to reductions in stratospheric ozone and global climate change
Atmos-pheric hazards	Outdoor air pollution	Increasing problem in many urban areas due to road traffic; also associated with old, heavy and manufacturing industries and mining; wind-blown dust also a significant problem in some areas
Water-related hazards	Surface water pollution	In urban areas, primarily from industrial and domestic wastes; in rural areas with co-use of waters for humans and livestock
	Drinking water contamination	Especially in areas without access to treated/piped water
Food-borne hazards	Biological contamination	Associated with poor domestic sanitation and hygiene arrangements
	Chemical contamination	E.g. food additives, pesticides
Vector-borne hazards	Water-related vectors	E.g. malaria, guinea worm, schistosomiasis
	Animal-related vectors	E.g. sleeping sickness, bubonic plague
Domestic hazards	Indoor air pollution	Especially associated with use of kerosene, dung, wood or coal in open fires for cooking/heating
	Domestic accidents	Often associated with over-crowding and poor living conditions
	Domestic violence	Often associated with over-crowding and poor living conditions
	Suicide	Often associated with over-crowding and poor living conditions
	Sanitation	Severe problem in areas lacking organised sewerage system (e.g. in informal settlements)
	Waste handling	Associated especially with open waste dumps – e.g. communities living on, or regularly sorting trough, waste sites
Occupat-ional hazards	Industrial pollutants	Especially in hazardous and unregulated industries (e.g. informal sector)
	Occupational accidents	Especially in hazardous/unregulated industries (e.g. informal sector)
Infra-structural hazards	Traffic accidents	Growing problem in major cities throughout Africa
	Industrial accidents	Associated mainly with poorly regulated chemical industries
	Contaminated land	Old industrial sites and waste-dumps

3.2 Environmental health hazard indicators

3.2.1 The concept of indicators

In order to map environmental health hazards, indicators need to be defined. These should provide a means of describing or categorising the hazard in terms of its importance or severity (its degree of hazardousness) and showing how this varies geographically.

Table 6. Quantifying environmental health hazard indicators

Approach	Measure	Comment
Hazard assessment	Geographic extent of hazard Magnitude of hazard Frequency/probability of hazard Duration of hazard	No single measure is able to take account of the different dimensions of 'hazardousness'. None of these measures takes account of the population distribution, and thus the number of people at risk.
Risk assessment	Numbers of people exposed Potential disease burden	Requires information on population distribution. Assessment of the potential disease burden requires knowledge of dose-response and/or exposure effect relationship; this is often not known with certainty. Relationships with health outcome may also be heavily confounded by other factors.
Health impact assessment	Number of reported cases Incidence rate Prevalence rate Standard morbidity rate Standard mortality rate	All these measures are retrospective and thus do not give an early warning of potential effects. Standard mortality and standard morbidity rates give a measure of the relative prevalence of the health outcome, but do not indicate the absolute disease burden. SMRs also need stratifying by age, gender etc where marked differences in rate occur within a population.

Various ways of assessing hazards are available. Focus may be placed on the hazard itself (a hazard indicator, *sensu stricto*), on the population at risk (a risk indicator) or on the health effects (a health impact indicator). Moreover, each of these types of indicator can be quantified using different measures (Table 6). Most hazards can be characterised by their geographic extent, their magnitude, their frequency or their duration, or by some combination of these. Most environmental health risks might be assessed in terms of the number (or percentage) of people at risk, or the imputed disease burden on the population. The health impact might be measured in terms of the number of cases, the incidence or prevalence rate, or the standard morbidity or mortality ratio. Each of these is likely to have certain advantages and disadvantages; which is most appropriate depends on the question which is being addressed.

It should be said that the concept of indicators is now relatively well established, and indicators are increasingly being used both for environmental and health mapping. The definition and compilation of effective indicators is, however, far more difficult than is often assumed. The purpose of an indicator in this context is to give the users useful, reliable and meaningful information about the hazard of interest. Generating indicators which achieve this requires careful thought. Table 7 provides a check-list of some of the key factors which need to be considered in trying to develop meaningful and reliable environmental health hazard indicators.

Table 7. Criteria for good environmental health hazard indicators

Environmental health indicators should be:

A. Scientifically valid

- based on a known linkage between environment and health
- sensitive to changes in the conditions of interest
- consistent and comparable over time and space
- robust and unaffected by minor changes in methodology/scale used for their construction
- unbiased and representative of the conditions of concern
- scientifically credible, so that they cannot be easily challenged in terms of their reliability or validity
- based on data of a known and acceptable quality

B. Politically relevant

- directly related to a specific question of environmental health concern
- related to environmental and/or health conditions which are amenable to action
- easily understood and applicable by potential users
- available soon after the event or period to which it relates (so that policy decisions are not delayed)
- based on data which are available at an acceptable cost-benefit ratio
- selective, so that they help to prioritise key issues in need of action
- acceptable to the stakeholders

(after Corvalan et al. *2000)*

3.2.2 An indicative set of environmental health hazard indicators

Based on these principles, it is possible to develop a set of potential indicators for the various environmental health hazards listed in Table 5. These are summarised in Table 8, and detailed guidance on how to define and construct them is given in Annex 2. Nevertheless, this list of indicators needs to be viewed with some caution, for two important reasons.

Table 8. Examples of environmental health hazard indicators

Category	Hazard	Hazard indicator	Risk indicator	Health impact indicator
Land/climate-related hazards	Volcanic activity	Area within 5 km of active volcanoes	Number (or percentage) of people living within 5 km of active volcanoes	Number of deaths (or mortality rate) due to injury by volcanic activity
	Earthquakes	Area of recorded earthquake activity within living memory	Number (or percentage) of people living within earthquake area	Number of deaths (or mortality rate) due to earthquakes
		Frequency of earthquakes > 5 on the Richter scale		
		Area with >10% probability of an earthquake > 5 on Richter scale within 100 years		
	Avalanches	Area of recorded avalanches in living memory	Number (or percentage) of people living within avalanche prone area	Number of deaths (or mortality rate) due to avalanches
		Probability of avalanche in worst-case weather conditions		
	Flooding/storms	Area within 100 year flood level	Number (or percentage) of people living within 100 year flood level	Number of deaths (or mortality rate) due to drowning
		Flood probability		
	Drought	Frequency of drought years	Number (or percentage) of people living within area with a drought frequency of greater than 1 year in 10 years	Number of deaths (or mortality rate) due to drought
		Mean annual rainfall		

Land/climate-related hazards (continued)		Mean annual precipitaion: evapotranspiration (P:E) ratio Area with >10% probability of drought	Number (or percentage) of people living within areas with a P:E ratio < 0.75	
	Hurricanes/wind	Hurricane frequency Area with >10% probability of hurricanes	Number (or percentage) of people living within area with a hurricane frequency greater than 1 in 10 years	Number of deaths (or mortality rate) due to hurricanes
	Soil erosion/ desertification	Area subject to severe soil erosion Mean annual soil erosion rate	Number (or percentage) of people living in area of severe soil erosion	
	UV radiation	UV index	Number (or percentage) of people living in areas with a UV Index > 5	Annual incidence rate for skin cancers Standard mortality rate due to skin cancers
Atmospheric hazards	Outdoor air pollution	Mean annual concentration of target air pollutants (e.g. SO2, PM10, NOx, lead) Percentage of days on which air pollution levels exceed WHO guidelines	Relative risk of respiratory illness due to air pollution	Hospital admission rate for respiratory illness Percentage of children under 5 years of age suffering from upper respiratory tract illness

Water-related hazards	Surface water pollution	Mean annual concentration of target water pollutants (e.g. BOD, faecal coliforms)		Incidence of diarrhoeal morbidity in children under 5 years of age
		Length (or percentage) of streams classified as 'poor' quality		Number of deaths (or mortality rate) due to diarrhoeal diseases in children under 5 years of age
	Drinking water contamination	Percentage of drinking water samples failing drinking water standards	Number (or percentage) of people reliant on contaminated drinking water	Incidence of diarrhoeal morbidity in children under 5 years of age
			Percentage of households (or population) served by untreated drinking water	Number of deaths (or mortality rate) due to diarrhoeal diseases in children under 5 years of age
Food-borne hazards	Biological contamination	Percentage of food samples failing food quality standards due to biological contamination (e.g. Salmonella, E. coli, Campolybacter)		Number of outbreaks of food-borne illnesses
				Number of deaths (or mortality rate) due to food-borne illnesses
	Chemical contamination	Percentage of food samples failing food quality standards due to chemical contamination (e.g. pesticides)		

Vector-borne hazards	Water-related vectors	Number (or population density) of water-borne	Number (or percentage) of people living in areas in which water-related disease vectors are endemic	Prevalence of water-related infections (e.g. of schistosomiasis, dracunculiasis, malaria)
		Percentage of water-bodies infected with disease vectors		Number of deaths (or mortality rate) due to water-related infections (e.g. of schistosomiasis, dracunculiasis, malaria)
		Area of potential breeding grounds for water-borne vectors		
	Animal-related vectors	Number (or population density) of animal-carriers (e.g. rats)	Number (or percentage) of people living in areas in which animal-related disease vectors are endemic	Prevalence of animal-related infections (e.g.sleeping sickness, bubonic plague)
		Area of potential breeding grounds for animal-related vectors		Number of deaths (or mortality rate) due to animal-related vectors (e.g. bubonic plague)
Domestic hazards	Indoor air pollution	Mean annual concentration of target pollutants (e.g. CO, NO 2, particulates) in domestic premises	Number (or percentage) of people reliant on kerosene, wood, dung or open coal fires for cooking/heating	Hospital admission rate for respiratory illness
				Percentage of children under 5 years of age suffering from upper respiratory tract illness
	Domestic accidents		Percentage of people living in inadequate or unsafe housing	Hospital admission rate for domestic injuries
				Number of deaths (or mortality rate) due to domestic injuries

Domestic hazards (continued)	Domestic violence		Number of reported cases of domestic violence	Hospital admission rate for injury by domestic violence
				Number of deaths (or mortality rate) due to domestic violence
	Suicide			Hospital admission rate for attempted suicide
				Number of deaths (or mortality rate) due to suicide
	Sanitation		Percentage of households (or population) not connected to sanitation services	
	Waste handling	Percentage of waste safely disposed by municipal waste services (e.g. by contained landfill, incineration)	Percentage of households not served by regular waste collection service	Prevalence of waste-related infections (e.g. bubonic plague, endemic typhus, leptospirosis)
		Area of unsealed waste sites		Number of deaths (or mortality rate) due to waste-related infections (e.g. bubonic plague, endemic typhus, leptospirosis)
Occupational hazards	Industrial pollutants		Number (or percentage of workers) employed in hazardous	Hospital admission rate due to acute occupational or unregulated industries exposures

Occupational hazards (continued)				Number of deaths (or mortality rate) due to acute occupational exposures
	Occupational accidents		Number (or percentage) or workers employed in hazardous industries	Hospital admission rate due to occupational injury or unregulated
				Number of deaths (or mortality rate) due to occupational injury
Infrastructural hazards	Traffic accidents	Average traffic speed in built-up areas	Number of reported traffic accidents	Hospital admission rate due to traffic accidents
		Vehicle energy index (speed x number of vehicles) in built-up areas		Number of deaths (or mortality rate) due to traffic accidents
	Industrial accidents		Number (or percentage) of people living within 1 km of hazardous industrial plants	Number of deaths (or mortality rate) due to industrial accidents
			Number of reported industrial accidents (e.g. fires, release of hazardous substances, explosions)	
	Contaminated land	Area of contaminated land		
		Area of unsealed waste sites	Number (or percentage) of people living on contaminated sites (including waste sites)	

The first is that the compilation of these indicators might not always be feasible, because suitable data are lacking (see section 3.3). In case, a proxy may have to be used. To be effective, proxies must not be capable of measurement; they must also have a close and known relationship to the hazard of interest (in other words, they must still *indicate*). The issue of malarial mosquitoes provides an example. The ideal indicator of this hazard might be seen as the population density of malarial mosquitoes (e.g. measured as the number per square kilometre) or – if the relevant data are not available – the area in which malarial mosquitoes are endemic. Even this information may not always be available, however. Then, a more indirect proxy might have to be used: for example, the distribution of potential mosquito habitats (e.g. standing water and marsh). This will only give a good proxy if it is reasonably closely related to the distribution, or population density, of malarial mosquitoes.

The second reason why the list of indicators given in Table 8 might not be appropriate is that indicators may need to be defined differently depending on the specific purpose for which they are intended, and the geographic scale of application. Where environmental health hazard mapping is being used to raise public awareness and empower local communities, for example, the indicator will need to have particular meaning for the people involved. In these cases, scientific accuracy may be less important than the relevance to the local community. Where mapping is being conducted as part of a scientific health risk assessment, on the other hand, the hazard may need to be quantified in much more rigorous terms. Equally, the sorts of indicators which might be used at the local scale will often differ from those required for international comparisons.

3.2.3 Steps in designing environmental health hazard indicators

For the reasons outlined in the previous two paragraphs, few indicators are universally applicable. Most need to be adapted according to the circumstances – i.e. the purpose for which they are to be used and the availability of relevant data. For many users this is an uncomfortable fact: they would prefer to have a simple, short and definitive list of indicators which they can measure everywhere. Reality is different. Rather than rely on ready-made lists of indicators, therefore, most users would be better to know how to construct a good indicator, which can make use of the available data and serve their specific needs.

One of the most important needs in this respect is to understand clearly the nature of the hazard to which the indicators relate. Several techniques are available to facilitate this understanding, but possibly two of the most effective are the construction of mind-maps and 'process-response models'. Both of these are attempts to present the main characteristics, determinants and effects of the hazard, and the links between them, in a way which enables key points of measurement or description to be identified. Mindmaps do this through a relatively free linkage and association of what are perceived to be the essential factors; they are especially helpful as part of brainstorming sessions between participants from different disciplines or sectors. Process-response models diagrams follow more rigorous rules; they aim to define the components of the hazard and the main causal dependencies or flows which link them. Examples relating to rock avalanche risks and traffic accidents are shown in Figures 4 and 5.

Figure 4. *A mindmap of rock avalanche hazards*

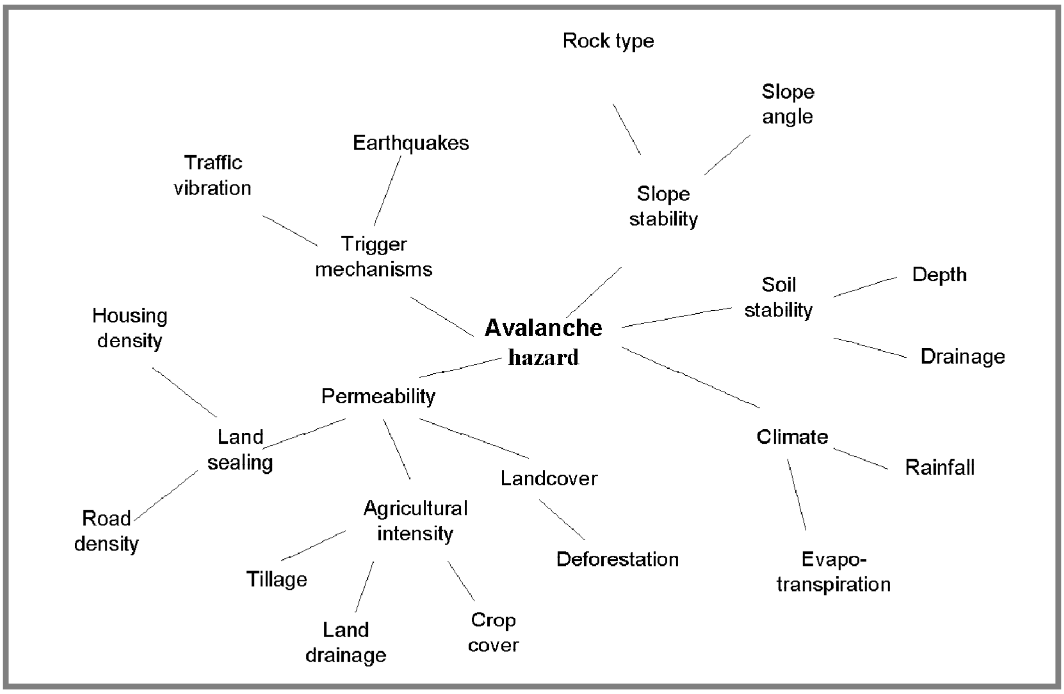
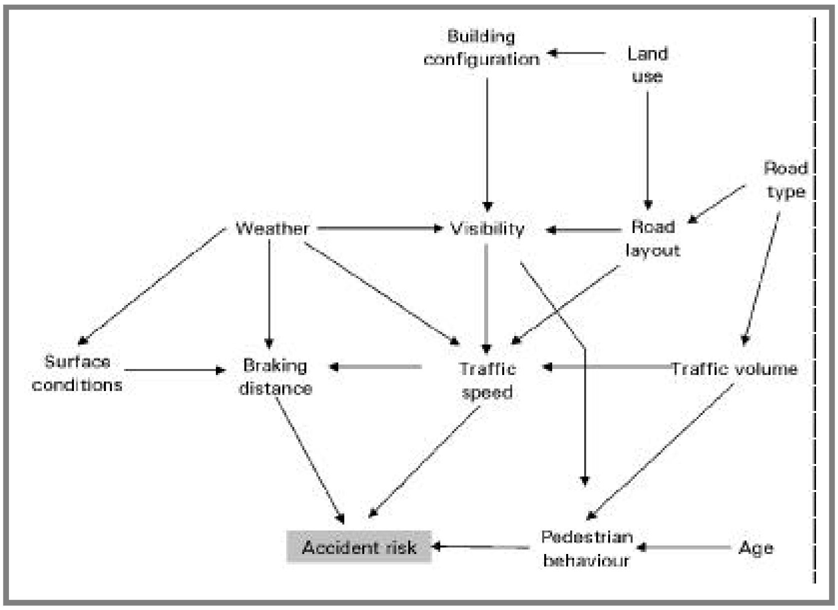


Figure 5. *Process-response model of road traffic accident risk*



In compiling indicators it is also useful to record clearly the definitions, data sources and computational methods used, together with a commentary on how it might be interpreted. The value of this is that it allows other users both to understand the indicator more clearly, and to develop consistent indicators if required. The indicator profiles presented in Annex 2 provide examples.

3.3 Data availability and quality

3.3.1 Data characteristics

The construction of indicators, by which to carry out environmental health hazard mapping, depends upon the availability of suitable data. Ideally, the necessary data could be collected according to need. Data collection, however, is both costly and time-consuming. For the most part, environmental health hazard mapping thus has to rely on existing data – or on data which can be easily obtained using existing systems. An increasing range of data is becoming available across the world (in Africa as elsewhere), due in part to developments in environmental monitoring and surveillance (e.g. using satellite technologies and other remote sensing methods). Nevertheless, few of these data systems have been set up for the purpose of environmental health hazard mapping. Whether the available data are appropriate for environmental health hazard mapping is therefore a matter of chance. As a consequence, data availability is likely to be an important constraint on the potential to develop environmental health hazard mapping in Africa, at least in the short-term. Some of the potential problems with environmental health hazard data, and the factors which thus need to be considered in evaluating the suitability of the available data, are listed in Table 9.

The various problems which beset the data do not need to prevent environmental health hazard mapping. Many problems can be overcome, for example by the use of estimation or modelling techniques, or by employing proxies. In general, the need is twofold:

- to make the best use possible of the data which do exist;
- in carrying out hazard mapping to acknowledge where data are lacking, and use the maps as a means of stimulating new data collection where it is most needed.

3.3.2 Sources of environmental health hazard data

Data on environmental health hazards – or more strictly, relating to the indicators which might be used to map environmental health hazards – are available from a wide range of sources. Given the need to rely as far as possible on existing data, six main sources are worthy of specific attention (Table 10).

Table 9. Issues in data availability and quality

Issue	Explanation
Data availability	Data may be unavailable due to: • lack of monitoring/survey etc (e.g. because the need for the data has not been recognised) • loss of data (e.g. due to fire, computer failure or administrative problems) Unavailability of data may require the use of proxies.
Data accessibility	Access may be limited by: • lack of knowledge about the existence of the data • confidentiality • copyright restrictions • cost • inappropriate storage media or formats Many of these problems can be addressed by negotiation and collaboration (e.g. by data exchange and data sharing).
Relevance	Much environmental data has not been collected specifically for health reasons, and may therefore not be relevant to environmental health. Relevance of data is not absolute: it varies depending on the needs of the user and the specific question being addressed.
Completeness	Gaps in the data may occur because of: • equipment/instrumental failure or damage • disruption of monitoring or surveys (e.g. due to war or funding problems) • administrative problems (e.g. data not processed, reported or stored) Gaps in data completeness can sometimes be filled by estimation procedures (e.g. interpolation) or by use of proxies.
Geographic	The geographic coverage defines the areal extent of the data. Coverage is often coverage inversely related to scale and resolution; small-scale data covers larger areas in less detail; large-scale data covers smaller areas in more detail. For environmental health hazard mapping, the coverage may need to vary, depending on how extensive the hazard is. Scale and Geographic scale refers to the ratio between the map and the reality it depicts;
resolution	resolution refers to the size of the smallest features depicted on the map. A crucial issue in environmental health hazard mapping is the size of the map units (e.g. administrative areas) used to present the data. Large areas (low resolution) may result in over-aggregation of the data, masking local patterns. Small areas (high resolution) may result in too much unnecessary data in the map and the 'small numbers problem' (i.e. values for some map units may be statistically unreliable).
Timeliness	Timeliness refers to the degree to which the data are up-to-date. For environmental health hazards, the extent to which the data need to be current will vary, depending on the temporal pattern of the hazard events and the latency period between the exposure and the health effect. For hazards which only occur very infrequently, or for which the latency period is very long (e.g. many cancers) up-to-date data may not be needed.

Temporal resolution	Temporal resolution relates to the averaging period of the data and determines the shortest event which can be distinguished. Since many hazards show a log-linear or log-log relationship between magnitude and frequency, short averaging periods are needed to identify the more frequent, small variations in the hazard. Where interest is only in the larger, less frequent events, longer averaging periods are acceptable.
Accuracy and precision	Problems of accuracy and precision often relate to inadequacies in: • sample design (e.g. unrepresentativeness) • measurement methods (e.g. use of inappropriate or poorly maintained equipment, use of inappropriate methods) • statistical or modelling errors (e.g. use of inappropriate or erroneous models) • reporting errors (e.g. errors in data transcription) • mapping errors (e.g. in georeferencing)
Consistency	Consistency refers to the extent to which data for different areas, or different periods, are directly comparable. Inconsistencies often occur due to variations or differences in: • sample design (e.g. sample location, size, timing) • measurement methods (e.g. laboratory procedures, field methods) • data analysis (e.g. statistical processing, aggregation methods, treatment of outliers) • reporting methods (e.g. timing of reports, data selection) Inconsistencies can often be checked by use of inter-comparison studies. In environmental health hazard mapping, inconsistencies are often most important when international, or inter-regional comparisons are being made.
Metadata	Metadata are data which describe the data (e.g. define the variables, explain how the data have been collected and analysed). Lack of suitable metadata often hinders access to and use of data. Good metadata can help users to identify and resolve deficiencies.

3.4 Mapping methods and technologies

In order to construct and map environmental health hazard indicators, such as those listed in Table 8, a range of data may need to be brought together, analysed and displayed. In mapping the extent or severity of soil erosion, for example, it may be necessary to bring together data on soil conditions, slope angle, rainfall and land use, in order to define high risk areas. Mapping of the risk from industrial accidents may require the ability to estimate the number of people living within a specified distance of major installations. Mapping the environmental determinants of a vector-borne hazard such as malaria, may require the overlay of data on wetland and water areas, climate and population.

Using traditional, paper-based mapping methods, these were all difficult tasks for the data are often available in different geographic formats (i.e. based on different map projections, or aggregated to different spatial units), which cannot easily be related one to another. With the development of computerised systems of mapping in recent decades, however, the capability for hazard mapping has been greatly enhanced. By providing the capability to store and manipulate data in digital formats, these can enable a wide range of procedures to be carried out with relative ease, including:

Table 10. Characteristics of data sources

Source	Examples	Weaknesses	Advantages
Existing maps	Soil maps Meteorological maps Geological maps	Features mapped, and classifications used, may not be appropriate for hazard mapping Map scales/resolution may not be appropriate Different mapping systems and formats may have been used in different areas or at different times May be out-of-date	Data do not need further processing Already in map form Widely available
Field survey	Household surveys Opinion surveys	Methods may vary between agencies/regions Often not up-to-date. Coverage may be incomplete or unrepresentative Level of aggregation (georeferencing) used may be too coarse	Often available in map form
Environmental monitoring	Air pollution monitoring Water quality monitoring	Generally sparse coverage Sampling regime may not be representative Methods may vary between agencies/ areas	Quantitative measurements Point located data Usually provides continuous or near-continuous time-series data
Census/ registration/ self-reporting	Waste licensing Emissions inventories	Accuracy may be poor Problems of inconsistency in methodology and reporting Confidentiality may limit spatial resolution and use of data	Usually up-to-date
Remote sensing	Satellite imagery Aerial photography	May require substantial processing/ interpretation effort May be costly to acquire	Widely available Consistent methodology can usually be assured Timely data normally available (especially from satellite imagery) Repeat data often available
Modelling	Pollutant dispersion modelling Hydrological modelling Expert	Accuracy may be unknown (models not validated) Accuracy depends on quality of model and input data Models may vary between areas/agencies	Can be used where other data not available Models can be improved without costly re-engineering or resurveys Provides prospective data (e.g. future scenarios)

- capture of geographic data
- transformation of data between different geographic structures
- integration and registration of these data to a common geographic base
- overlay and intersection of different data sets
- spatial modelling and interpolation of geographic data
- representation of the data in a wide range of different map and other forms

Table 11. Advantages and disadvantages of different mapping systems

System	Examples	Advantages	Disadvantages
Full GIS	Arc Info SPANS ArcView MapInfo	• does not require development and programming • good manuals and system support • many data sets already available in the required format • ease of data transfer between systems • regular upgrades available • great flexibility and functionality	• may be expensive to purchase (especially in large numbers) • may be complex to use and have high training requirements and costs • may be over-engineered relative to needs of user
Desk-top mapping systems	MapMaker Manifold	• cheap to purchase • easy to use • provide links to more powerful GIS and common spreadsheet/ database packages	• limited analytical functionality
Map viewers	ProViewer ArcExplorer	• very cheap to purchase • compilable programmes, can be transferred with data • very easy to use • can accept data from major GIS packages	• little or no editing capability • no analytical functionality
Purpose-designed systems	Healthmap EpiInfo	• can be designed and customised to need • may be cheaper to provide in large numbers than proprietary systems • may need less expertise to use than a full GIS	• upgrades depend on continued development by the programmer • support and maintenance may not be reliable • problems of compatibility with other GIS and spreadsheet/ database packages

There are, however, several different approaches to computerised mapping which might be considered for environmental health hazard mapping. One approach is to use proprietary geographic information systems (GIS). These take many forms, but typically comprise an integrated software package, including functions for all the operations listed above. Widely used examples include powerful analytical systems such as ArcInfo and SPANS, intermediate systems such as ArcView and MapInfo and low-level desktop mapping packages, such as MapMaker and Manifold. Simple, compilable package are also available (e.g. ProViewer and ArcExplorer) which can read data in more common GIS formats, and allow them to be displayed outside the GIS. Alternatively, purpose-designed mapping software can be developed, using progamming languages such as C, C++ or VisualBasic. Examples include the EpiMap and Healthmap software, both developed for WHO.

Each of these approaches has both strengths and weaknesses (Table 11). In general, however, it might be suggested that it is more appropriate to use established, proprietary GIS where these are available and can be afforded. These have two crucial advantages over purpose-designed systems: the availability of continuous system support, and their greater functionality. Both of these are important. The capacity and quality of system support is essential because, as the number of users grows, and the range of operations they wish to carry out expands, increasing demands are likely to be made on the suppliers for trouble-shooting, software enhancement, training and advice. Extended functionality is equally vital, because users' needs change as they become more adept at using the software, and as they try to tackle new problems and analyse new data sets. In particular, users tend rapidly to outgrow the need simply to map data and instead wish to investigate and analyse their data in more advanced ways. This is likely to stretch most purpose designed mapping systems beyond their limits. The added functionality – and greater flexibility – of most proprietary GIS also has other benefits. In particular it means that GIS can often serve the needs of several different users. In turn, this helps to establish a group of users who can help and learn from each other; to encourage data sharing; and to make the systems more affordable by facilitating cost-sharing (not only of system purchase, but also training, system support and data acquisition).

3.5 Is environmental health hazard mapping feasible in Africa?

Section 3.1 summarised some of key environmental health hazards of concern in Africa; in section 3.2 (and in more detail in Annex 2) a set of indicators was defined for mapping these hazards. This section examines the extent to which these – or similar – indicators can in fact be defined, measured and mapped within Africa. This assessment is carried out in relation to three sets of considerations:

- data availability and quality
- technical and personnel issues
- administrative and financial issues

3.5.1 Data availability and quality in Africa

As the preceding section has indicated, data availability and quality are important constraints on the potential to carry out environmental health hazard mapping. Certainly in Africa, data availability and quality are far from optimal. Problems have included lack of resources for surveys and monitoring, political upheaval, disruptions caused by famine and war, and inappropriate administrative systems. Much *basic map data* (e.g. topographic data) may be out-of-date in many areas, or of variable dates, and of low spatial resolution. Few of these data are already available in digital form, except in the case of the low resolution data (e.g. DCW). Problems of confidentiality (e.g. for military reasons) are also common. *Environmental data* are also often scarce and of uncertain quality, especially in more remote areas. Monitoring systems, for example, are relatively sparse, and often concentrated only in the larger cities (and there often in limited areas). Survey data (e.g. on soils, geology) tend to be available only at relatively coarse scales. *Population* – and other *census* – data are also prone to inaccuracies because of incomplete reporting, and may be highly inconsistent between countries or regions because of differences in definitions, census dates and reporting quality. Administrative boundaries or locations may also not be clearly defined, making integration of population and other data difficult. *Routine health data*, where they exist, are often not adequately geocoded and may be available centrally only at highly aggregated levels, or locally only in paper form. Considerable effort may therefore be needed in capturing suitably georeferenced data. Problems of inconsistencies and uncertainties in diagnosis also occur.

On the other hand, a growing recognition of the need for reliable environmental and health data is emerging in many countries, while the development of remote sensing technologies is greatly increasing the potential for environmental survey and monitoring. Activities by international agencies (including WHO, UNICEF, UNDP, UNEP and the World Bank) are also helping to improve data availability in many areas. In addition, there is a growing tendency to carry out household surveys, which are providing an increasing body of relevant social data of relevance to environmental health hazard mapping. Considerable scope does exist, therefore, to obtain relevant data, at least in some parts of Africa, and the possibility of developing routine systems for data collection is undoubtedly improving. Whilst there may be few areas that are yet able to establish comprehensive systems of environmental health hazard mapping, opportunity to develop at least prototype systems does exist in many areas.

Table 12 summarises the situation in relation to the hazards identified in Table 5, and the data sources listed in Table 10. It should, however, be stressed that this assessment is both general and generic; the situation in different countries is likely to vary substantially.

3.5.2 Technical and personnel issues

Access to suitable systems for data capture, data management and mapping is clearly vital if environmental health hazard mapping is to be carried out effectively. As noted previously, this implies the availability of computerised mapping systems, either in the form of proprietary GIS or as purpose- designed mapping systems. Based on the arguments presented above, the use of proprietary GIS is

Table 11. Potential sources of environmental health hazard data in Africa

Category	Examples of hazards	Existing maps	Field survey	Environ-mental monitoring	Census/ regist-ration	Remote sensing	Model-ling
Natural hazards	Volcanic activity	XXX	XX	XX		XXX	XX
	Avalanches	XX	XX			XXX	XX
	Earthquakes	XXX	XX	XX		XXX	XX
	Flooding/storms	XX	XX	XX		XXX	XX
	Drought	XX	X	XX		XXX	XX
	Hurricanes/wind	XX	X	XXX		XXX	XX
	Lightning strikes			XXX		XX	XX
	Soil erosion/ desertification	X	X	X		XXX	XX
	UV radiation		XX	XX			XX
Atmos-pheric hazards	Outdoor air pollution	X		XX	X	X	XX

Water-related hazards	Surface water pollution	X	X	XX	X	X	XX
	Drinking water contamination		XX	XX	X		X
Food-borne hazards	Biological contamination		XX	X	X		
	Chemical contamination		XX	X	X		
Vector-borne hazards	Water-related vectors		XX	X	XX	X	X
	Animal-related vectors		XX	X		X	
Domestic hazards	Indoor air pollution		X	X			X
	Domestic accidents		XX		XX		
	Suicide				XX		
	Sanitation		XXX		XX		
	Waste handling		XX		X		
Occupa-tional hazards	Industrial pollutants		XX	XX	X		
	Occupational accidents		XX		X		
Infrastruc-tural hazards	Traffic accidents				XX		X
	Industrial accidents				XX		X
	Contaminated land		X			XX	
Social conflicts	War		XX		XX	X	
	Domestic violence		X		XX		

Key: XXX = Good sources of data for much of the continent
XX = Good sources of data, but currently provide limited coverage
X = Potential sources of data, but not yet developed considered to be more appropriate if environmental health hazard mapping is to be established as a routine tool. For developmental purposes, however, simpler systems such as EpiMap and Healthmap may also be of utility.

The availability of GIS in the organisations likely to be undertaking environmental health hazard mapping in Africa is inevitably limited. Few ministries of health, district health authorities or health care agencies currently make use of GIS or have experience in its use. Much of the expertise which does exist tends to reside not in the health sector, but in the sectors of government concerned with environmental and resource management and urban planning, in university departments in these areas and in private agencies (environmental consultancies, public utilities etc). Considerable developmental work thus needs to be done in the health sector, both to raise awareness about GIS, and to establish expertise in its use.

Nevertheless, the situation is undoubtedly improving. The availability of, and expertise in, GIS is expanding rapidly in Africa as elsewhere – encouraged by the wider availability of the technology, by easier access to training, by falling costs of systems and by the Internet. In the medium- to long-run, therefore, technology is unlikely to be a major constraint. In the shorter-term, much can undoubtedly be achieved with the technologies which already exist, or with the simpler, entry-level systems which can feasibly be established (e.g. the WHO-sponsored products such as EpiInfo and Healthmap, or the low-cost mapping systems such as MapMaker). Though these do not provide the capability for advanced data overlay or modelling, they do provide serviceable packages for mapping. They thus have particular potential in raising awareness about environmental health hazard mapping, and in providing introductory experience in mapping for the personnel concerned. Much can also be achieved by drawing together, and drawing on, the expertise and facilities which exist outside the health sector. The advantages for these sectors in collaborating with each other, and with the health sector, are considerable. Collaboration offers the opportunity to exchange and share the experience which does exist, to gain access to and share data, to generate greater demand for GIS-based services and experience, and to attract increased resources into this area. Efforts to encourage collaboration are thus likely to be welcomed, at least amongst the professionals involved.

At the same time, it needs to be recognised that formal training will need to be provided if the necessary GIS skills are to be developed. This implies access to suitable training courses – whether in the form of high level postgraduate programmes or intensive GIS courses and workshops. These are now becoming more readily available, but there is a need both to promote the opportunities more actively (e.g. through WHO newsletters and seminars) and to help in providing funding for training.

3.5.3 Administrative and financial issues

Whether or not environmental health hazard mapping can be developed in Africa will depend to a very great extent upon the administrative and financial situation. Administrative support is essential, both to provide the necessary resources and to ensure that hazard mapping is seen as a valid and central part of decision-making. Significant investment is also likely to be needed not only in purchasing and maintaining computer hardware and software, but equally in ensuring availability of, and access to, relevant data.

The administrative difficulties facing the development of environmental health hazard mapping should certainly not be under-estimated. As noted earlier, the concept of environmental health hazard mapping is founded on the premise of a strategic, information-based approach to decision-making. If this does not exist, then the relevance of hazard mapping is unlikely to be recognised, and indeed efforts to provide more comprehensive, detailed and open data may be viewed with suspicion. Nor is the establishment of environmental health hazard mapping a one-off action. It implies continuity in data collection, data provision and analysis, which in turn assumes the existence of relatively stable administrative systems, with the capability to make long-term plans and commitments of resources. The multi-sectoral nature of most environmental health hazards also poses challenges, for it means that ministries and departments which have traditionally not always worked together must pool their efforts and resources. This need for a more multi-sectoral approach is, however, a two-edged sword. Without it, environmental health hazard mapping is unlikely to be successful, if only because the relevant data and resources are unlikely to be available. On the other hand, the importance of environmental health hazards in many parts of Africa can help to encourage this more multi-sectoral approach. If so, it is likely to bring benefits far beyond those of the hazard maps themselves. Either way, action to encourage cross-sectoral collaboration must be a priority.

As this implies, the establishment of environmental health hazard mapping may have far-reaching administrative implications. If successful, it is likely to reinforce – or help to instil – a more collaborative, strategic and objective approach to decision-making. Experience from similar development (e.g. the development of GIS-based approaches to planning control in local authorities) also shows that it may encourage new ways of working and create significant shifts in power and influence within the organisations concerned. Adjusting to these changes can be a significant challenge for the organisations concerned.

If the administrative issues pose challenges, the costs of establishing environmental health hazard mapping may seem even more formidable. The costs involved are many. They include:

- equipment purchase (computers, software etc)
- system maintenance and operation
- training and staff development
- data collection and capture
- data checking, geocoding and quality control

Of these, the costs of data collection, capture and management typically account for the largest share. Generalisations must be treated with caution, for much depends on local circumstances (e.g. of data availability) and how costs are attributed and charged. Experience of establishing computer-based systems of mapping in other sectors (e.g. planning, environmental management, the public utilities), however, suggests that data collection and management may be expected to represent as much as 80% of the total cost. This reflects the need not only to capture and georeference existing data (e.g. by digitising maps or encoding attribute data), but also to develop new systems for monitoring, survey, data reporting and data exchange.

By comparison, the costs of system purchase are relatively small. The basis elements of a mapping system will include the GIS software, a pc, a colour printer and suitable input devices (e.g. a digitising tablet and scanner). The total costs of these can vary substantially, depending on the level of sophistication involved – from about US$4-5000 for the simplest of systems, to US$50-70,000 for a high grade system. A relatively high-powered GIS (such as ArcInfo), for example, is likely to cost in the order of US$20-50,000. A less advanced system, such as MapInfo or Arcview can be obtained for about one-tenth of that. The cheapest mapping systems may cost no more than US$200-500. Costs also depend on the number of licences (i.e. users), the amount of training required, and the level of technological support. The last of these certainly needs to be given special attention. As experience in GIS and mapping builds up, expert external support (e.g. from vendors or consultants) becomes less significant. In the early stages of development, however, it can be crucial to ensuring that the system is installed and configured properly, and that those involved can maintain and use it effectively. Appropriate system support thus needs to be built into the costs. Table 13 gives some indicative costs of establishing a mapping system, based on a proprietary GIS, as guidance.

Table 13. Indicative costs of establishing a GIS-based environmental health hazard mapping system

Item	**Description**	**Indicative cost (US$)**	**Comment**
Hardware	pc	2500	Standard 600 Mhz pc with 17" monitor, 20 Gb hard-disk, 128 Mb RAM, CDRom, NT or Windows 98
	peripherals	1200	scanner, digitising tablet, printer
Software	proprietary GIS (e.g. ArcView, MapInfo)	5000	May range from US$300 for simple mapping package US$50,000 for a top-end GIS
System maintenance	software support and helpline	2000/yr	Varies depending on level of support
Staff training	intensive GIS training course (for 2 persons)	2000	Varies depending on complexity of system
Running costs	consumables	1500/yr	Depends on level of usage: mainly printing and telecommunication costs
Data collection	Data collection, capture, cleaning etc	?	Depends upon amount of data required, existing availability and quality of data, ownership and charging system etc

These costs do not necessarily arise all at once, nor fall on a single organisation. Whilst the costs of system purchase and training represent up-front investments, for example, the costs of data acquisition and capture, as well as system maintenance and running costs, can be spread over several years. Possibly the most effective cost strategy is thus to develop the system incrementally. Initially, a relatively simple system can be installed, which is designed to be used only by a small number of people and with readily available data. Data and users can then be expanded gradually, as opportunities permit. This has the advantage of allowing the longer term applications of the system to become apparent, before expensive investments are made, and for experience to be shared more effectively. This is important, for typically the full demands on, and applications of, the system cannot easily be defined at the start, when potential users are still unfamiliar with the technology. Once the system is operational, however, many, often unexpected, users and uses tend to emerge. This allows the development of the system to be better customised to need, and the costs of development to be more easily shared.

In the long-term, also, environmental health hazard mapping promises significant benefits. These include direct financial savings, as well as social returns – for example, by helping to prevent or minimise costly disasters, by reducing the need for health care, and by improving economic productivity and reducing production losses and associated costs. If these benefits are properly accounted, then the long-term benefit-cost ratio of environmental health mapping is likely to be positive; at worst it should be cost-neutral.

4. Developing environmental health hazard mapping in Africa

4.1 Possible development strategies

The preceding analysis has argued that environmental health hazard mapping is both useful and feasible in Africa. At the same time it is evident that the capacity to introduce and implement environmental health hazard mapping varies greatly across the continent, and in many areas neither the experience nor the facilities to establish hazard mapping are yet fully developed. If environmental health hazard mapping is to become established, therefore, action is needed to raise awareness and build capacity at both national and local level.

An important question in this context is how best to encourage this development. The adoption and establishment of any new approach or technology is rarely smooth and trouble-free. Many different forces often conspire to resist innovation, including suspicion and distrust, fear, lack of understanding and lack of expertise. In many cases, these concerns may be well-founded: not all innovations are beneficial! The question of how best to promote and disseminate the use of environmental health hazard mapping is thus an important one. Getting it wrong can cause substantial delay and unnecessary cost and may, in some circumstances, kill off what would otherwise have been a beneficial development.

Two opposing innovation strategies are often identified: the top-down and the bottom-up approach. The former may be characterised as one in which innovation is made corporately, based upon an agreed strategy and a clear set of goals. In the area of information systems (in which environmental health hazard mapping falls), this will typically include agreement about issues such as data needs and standards, the technologies to be used, data exchange and access procedures, and arrangements for system maintenance and development. Consistency is often the watchword, since the aim is to establish a common system which can be used by all parties concerned in a comparable way.

The bottom-up approach, by comparison, is likely to be more individualistic and often problem-led. Development and adoption of the innovation occurs locally, in response to specific needs and there is not necessarily any attempt to formulate coherent, common strategies between different sets of users. Fitness for local purpose is thus the over-riding concern. Development often occurs adventitiously, as new problems and needs arise, or as new opportunities to extend the system (e.g. new funding, new expertise, new data) become available.

Each of these approaches has both strengths and weaknesses, as outlined in Table 14. In many ways, however, the distinction between them is overly simplistic and divisive, especially in areas such as Africa, where great variations in existing capacity occur. In these situations, it rarely makes sense to rely on a heavily top-down approach for this may only act to delay and limit development. Nor is it possible to depend wholly on a bottom-up approach, since local capacity is often inadequate to develop the new technology effectively and in isolation. Instead, the need is to marry the two approaches. On the one hand, local developments need to be facilitated, where these can occur, in response to local needs and geared to make the best use possible of the knowledge, data and facilities that already exist. Longer term capacity building can meanwhile take place in those areas where opportunities are more limited. At the same time, standards and protocols can emerge as the technology develops and needs become more clearly defined.

Table 14. Strengths and weaknesses of different innovation strategies

Innovation strategy	Strengths	Weaknesses
Top-down	*Economies of scale* • sharing of data, equipment, expertise • corporate buying can save costs • enables cost-sharing *Enables bigger picture to be seen* • comparable data available across wider area/range of themes • allows trans-national problems to be more easily tackled • allows international priorities to be identified and set *Encourages collaboration, e.g. in* • data gathering/surveillance • policies/strategies	*Needs strong co-ordinating body* • to establish standards/protocols • to force agreement *Delays in implementation* • nothing done until agreement on standards etc reached *May not be appropriate for all partners* • some partners may not be able to achieve standards (may result in some partners being left out, or the dilution of standards to the lowest common denominator) • may impose unacceptable burdens on some partners (e.g. demands for data) which give no local benefit
Bottom-up	*Ensures fitness to local purpose* • systems designed to be optimal for each separate user, locally • can make best use of locally available data and expertise • more responsive to local need *Allows local issues to be tackled immediately* • innovation is problem-led • systems can be developed or adjusted in response to new problems	*Parochial view* • different areas/issues likely to be seen in isolation • difficult to examine or assess trans-national problems • impairs ability to develop internationally agreed objectives and strategies *Piecemeal development* • limited scope to share experience and expertise • limited opportunities to share data

On this basis, therefore, a more mixed approach to innovation perhaps needs to be pursued (Figure 6). In the early stages of development, local innovators can be allowed, and encouraged, to emerge. Within these, local priorities will need to drive the development, not least because these provide the justification for the development costs, and help to encourage interest and support within the organisation. As the local systems develop and become more widely demonstrated, however, they will tend to attract new interest from other potential users; this will lead to recognition of the need for a more collective approach. At the same time issues of data availability, data costs and limitations of technology and expertise will probably become apparent, further encouraging contact and collaboration between different agencies. A more integrated strategy should thus begin to emerge (and can be encouraged by WHO and national agencies). This will permit the development of more common standards and working methods, with arrangements for data sharing and exchange. Local systems begin to coalesce and the advantages of moving towards a more common approach become apparent. Gaps in data coverage and weaknesses in the available technologies become more evident and action is taken to address them (both by the users themselves and by data/equipment suppliers). At the same time, however, new issues and opportunities tend to emerge, often in different sectors and areas of interest, and often needing new methods and approaches. These tend to stimulate new, local initiatives, sparking off a new cycle of development.

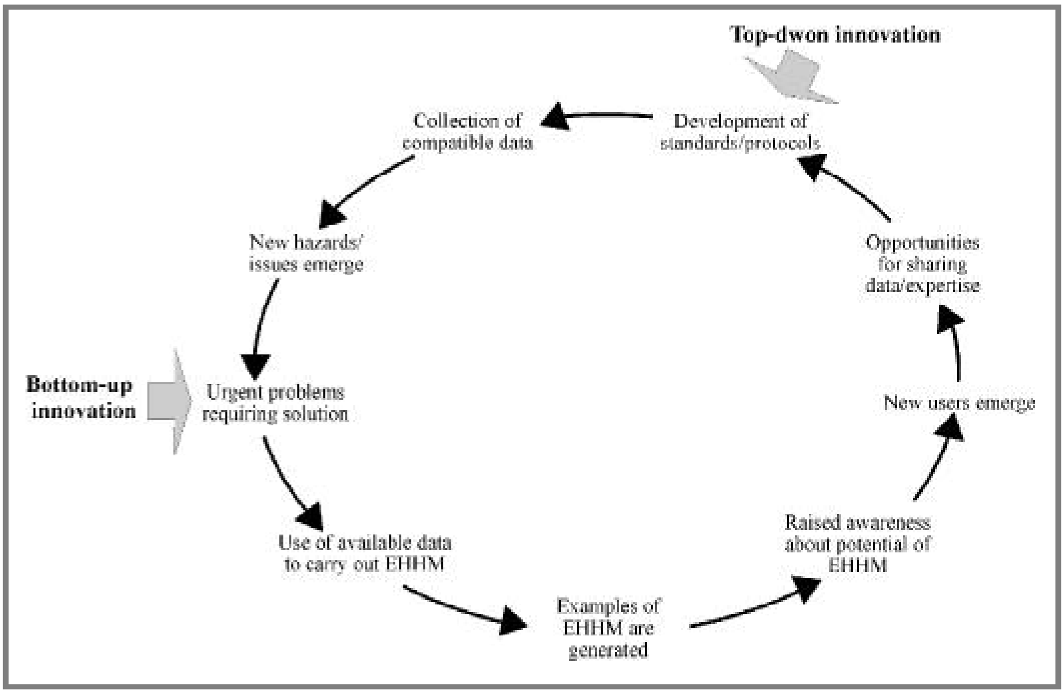


Figure 6. Strategies for developing environmental health hazard mapping

If this general approach to development is accepted, it implies the following logic:

1. the principle of making the best possible use of the capacity which exists to tackle local priorities and problems should underpin the development process;
2. local awareness-raising is essential to help stimulate development and identify key priorities;
3. sharing of experience is an essential and powerful means of development;
4. a multi-sectoral and cross-institutional approach is vital, in order to bring together the existing experience, data and facilities;
5. training and capacity building needs to be ‘seeded’ in areas where it can then flourish and from where it can spread;
6. the development of common standards and protocols – and thus the emergence of more general, Africa-wide systems for environmental health hazard mapping – should be seen as a second-stage process, occurring as local approaches mature and begin to coalesce.

4.2 The way forward

WHO clearly has a major role to play in developing environmental health hazard mapping in Africa. Together with other international organisations (e.g. UNDP, UNESCO, World Bank), and in collaboration with national organisations (e.g. ministries of health and environment), it should take a lead in:

- raising awareness at the national and local level
- encouraging the sharing and exchange of experience
- encouraging a multi-sectoral and cross-institutional approach
- building national and local capacity
- in the long term, developing standards, protocols and methodologies

4.2.1 Awareness-raising

Awareness-raising is an important priority. Currently, awareness about the benefits of, and opportunities for, environmental health hazard mapping is patchy and weak, especially amongst more senior decision-makers (at national and sub-national level) who have the power to encourage and resource its development. Indeed, until this awareness exists, it remains difficult to evaluate with confidence either the need for environmental health hazard mapping, or the real potential to develop it. An important priority is thus to raise awareness about environmental health hazard mapping so that:

- opportunities and needs can be more clearly assessed
- local development can be stimulated

Awareness-raising can be fostered in a number of ways, for example through:

- workshops and seminars
- formal and informal publications (e.g. reports, newsletters, research papers)
- Web-based dissemination

Awareness-raising, however, needs to be based on clear and practical evidence. Examples, case studies and demonstration systems are powerful tools. Several such examples exist; the need is to translate them into an instructive and accessible form. Others might readily be developed.

WHO clearly has a major role to play in this process. Early priorities should be:

1. to establish a project to compile and make available a set of demonstration systems and case studies
2. to organise ‘seed’ seminars to demonstrate the capability of environmental health hazard mapping and initiate discussion on its potential
3. to establish a Web site, providing examples of, and links to, environmental health hazard mapping

4.2.2 Sharing and exchange of experience

As has been noted, the availability of expertise and experience in environmental health hazard mapping, and in the use of relevant technologies such as GIS, is limited in Africa. Much of the relevant expertise which does exist lies outside the health sector, and has been focused on issues other than health – for example, urban planning, natural resource management. A locally focused, bottom-up approach to development will also mean, inevitably, that new experience will accrue locally and often in relative isolation. Sharing and exchange of experience are thus crucial if environmental health hazard mapping is to develop successfully and cost-effectively.

Once momentum is built up, much of this exchange of experience will occur naturally – for example, through professional contacts, through informal networks, through the use of bulletin boards and helplines, and via publication and dissemination of the work. In the short-term, however, help is needed to facilitate this process, for example by:

- organising workshops and seminars for practitioners
- setting up networks of practitioners
- supporting staff exchanges and study visits

A valuable start to this process would be to identify, bring together and support an expert group of individuals and agencies who already have experience in environmental health hazard mapping. Such a group could help to develop and test mapping methods and standards, and to provide case studies, examples and models for use in training and promotion. Initially, it might be envisaged that this group should comprise a small number of more advanced organisations (perhaps 5-8). It might be expected to include teams or individuals from both the health and environmental sectors, from both government departments and universities. The inclusion of overseas participants, with relevant experience, might also be beneficial. Over time, the group could build into a more formal network of practitioners, providing mutual support on technical matters and contributing to workshops, seminars and other training activities.

4.2.3 Fostering a multi-sectoral and cross-institutional approach

Environmental health hazard mapping is a wide-ranging concept. It touches upon, and has relevance to, many different areas of responsibility and draws upon many different areas of expertise. The different sectors involved, for example, include not only health and environment, but also the many areas concerned with the driving forces behind environmental health hazards: agriculture, industry, urban development and planning, transport. These interests and responsibilities may also operate at many different levels, from the international to the local. Relevant areas of expertise include not only environmental health, epidemiology and environmental science, but geography, cartography and statistics, as well as the many disciplines specific to particular hazards (e.g. geology, climatology, chemistry).

Development of environmental health hazard mapping thus requires a multi-sectoral and cross-institutional approach. It needs to bring together and make use of both the different sectors involved and, within any single organisation, the different areas of expertise and responsibility.

WHO itself should be the starting point for this process. Within WHO, several different divisions and units have interests in the development of environmental health hazard mapping, and the tools (e.g. indicators, GIS) which underlie it. These include all areas which deal with environmental health hazards in one form or another (e.g. natural disasters, vector-borne diseases, food-borne diseases, industrial and occupational hazards), as well as those concerned with specific vulnerable groups (e.g. children) or with wider issues of risk assessment and communication. Several of these different groups, in different parts of WHO, are already involved in some way with developing relevant systems and methods. Examples within WHO-Afro, include not only DES, but the groups responsible for emergency response and preparedness (Emergency and Humanitarian Action Unit), infectious diseases (Malaria Unit), the immunisation programme (Extended Programme of Immunisation) and Health Situation Analysis. Elsewhere in WHO, related developments are occurring – for example:

- on the development of Healthmap (WHO-HQ)
- on environmental health indicators (WHO-HQ)
- on environmental health information systems (ECEH-Bilthoven)

The relevant experience, interests and – in time – resources within WHO (both in Africa and elsewhere) thus need to be drawn together. Within WHO-Afro, this might be best achieved by establishing an inter-divisional working group, with the remit to define common interests, explore ways of improving collaboration and sharing contacts with expertise in the member countries. Collaboration with other areas of WHO might be effected by encouraging WHO-HQ to organise and fund a workshop on environmental health mapping, and by setting up an internal network of interested parties.

Various other international agencies similarly have interests and experience relevant to environmental health hazard mapping: for example, UNEP/UNDP, UNESCO, FAO, OECD, WRI and the European Union. Contact with these agencies similarly needs to be developed. GIS vendors also have an important role to play, both by developing relevant tools for environmental health hazard mapping, and in providing training, support and favourable purchasing arrangements within the member countries.

In the long run, however, the most important collaboration needs to occur at the national and sub-national levels. WHO can certainly play an important part in encouraging this. An especially effective approach is to develop national and regional networks: i.e. comprising lead personnel from different sectors within different countries, perhaps arranged regionally to reflect common interests and concerns. The existing regional structure within WHO-Afro might serve this purpose. If so, it implies the need to brief the regional offices about environmental health hazard mapping, and to involve them in the development process. Several established partnerships and expert groups already exist, which might also provide a basis for networking (e.g. the team of national experts on emergency preparedness). Consultation needs to take place within WHO-Afro to identify these teams and, where appropriate, co-ordinate activities.

At the national level, this process then needs to be replicated, in order to provide a network of collaboration, both horizontally (within and between different sectors at one level of government), and vertically (between different layers of government). WHO can facilitate this process in various ways: for example by developing and disseminating an 'address book' or directory of expertise, and by supporting study visits and mini-workshops in the member countries.

4.2.4 Building national and local capacity

There is an important need for capacity building at the national and local level if environmental health hazard mapping is to be developed and applied successfully. This needs to cover almost all aspects of the hazard mapping process, including:

- the development of relevant methods and technologies
- data collection
- the design and construction of indicators
- the use of hazard information in decision-making

Training is an important part of this capacity building. Training needs to be aimed at:

- senior decision-makers and senior professionals to raise awareness about the potential value of environmental health hazard mapping and how it might contribute to planning
- at technical staff and more junior professionals to improve expertise in the techniques of environmental health hazard mapping

As noted earlier, the development of expert networks is also important, since these can help to:

- encourage the sharing of expertise and experience
- encourage data sharing
- promote collaboration and sharing of facilities
- establish self-help groups

To encourage and support training, WHO can take the lead in a number of ways, for example by:

- publishing guidelines and manuals on environmental health hazard mapping (see section 4.2.5)
- developing and disseminating demonstration packages and case studies
- organising training sessions and short-courses
- liaising with course providers, to help devise and customise training programmes
- providing a directory of training opportunities and of relevant expertise (e.g. via the Web)
- offering financial support for training (e.g. bursaries or travel grants)

Assistance also needs to be given in building up the technical infrastructure required for environmental health hazard mapping – e.g. computer hardware and software. WHO is already active in this respect, through the development and dissemination of mapping packages such as EpiInfo and Healthmap. As argued earlier, however, these systems are likely to be too limited to meet the longer term needs of environmental health hazard mapping. This might be better served by access to proprietary GIS. To a significant extent, WHO can facilitate this by encouraging contacts between the various sectors and agencies at national level (section 4.2.3). It may also be able to have an effect by establishing a database or a Web gateway to relevant models and methods (e.g. developed by universities): a facility of this type might easily be established by funding a small study. In addition, WHO could take a lead role in negotiating with GIS vendors, with the aim both of providing bundled software and data for environmental health hazard mapping as part of proprietary systems, and of arranging favourable purchasing terms.

Equally important is the development at national and local level of improved capacity for data collection and reporting. As has been noted, lack of data remains one of the most important constraints on the use environmental health hazard mapping in many parts of Africa. To a great extent, development of data collection facilities is a long-term process, requiring substantial investment at the national level. As such it is only likely to come as part of more general changes within the countries concerned. In the shorter term, however, effective assistance can be given, for example by:

- encouraging data exchange between different organisations
- raising awareness about data sources and data availability (e.g. a ‘data directory’)
- developing guidelines for data collection and reporting
- establishing and maintaining a set of environmental health hazard indicators

The basis for the last of these already exists, in that several organisations have compiled and published lists of indicators, many of which are relevant to environmental health hazard mapping. The list maintained on behalf of WHO-HQ (at www.northampton.ac.uk/ncr/who/) provides profiles for ca. 50 indicators, and links to other indicator sets. This source might usefully be further developed and customised by WHO-Afro to provide a core set of environmental health indicators (including those in Annex 2 of this report) and connections to useful data sources.

4.2.5 Developing standards, protocols and methodologies

To encourage and support development of environmental health hazard mapping at the local and national level, there is the need for a simple 'user manual'. This needs to cover the numerous technical issues involved in environmental health hazard mapping, including:

- modelling and characterisation of environmental health hazards
- methods for assessing environmental health hazards
- indicator development and construction
- mapping methods and map design

Because the technical requirements for environmental health hazard mapping are, to a great extent, context dependent, this manual should present specific guidance for mapping of different types of hazard (e.g. acute, chronic) and at different geographical and administrative scales (e.g. international, national, local).

The technical components of this report provide a starting point for such a manual; experience within the member states could greatly add to what is contained here. WHO-Afro should therefore commission further work to develop a manual on environmental health hazard mapping, drawing on national examples and experience.

5. Conclusions and Recommendations

5.1 Conclusions

5.1.1 A definition of environmental health hazard mapping

Environmental health hazard mapping can be defined as *a set of methods for mapping and analysing the distribution, character and magnitude of environmental conditions and processes which might pose significant threats to human health*. As such it focuses on the **causes** of environmental health impacts and the **potential risks** to human health. It thus needs to be distinguished from, but provides a vital precursor to, both risk mapping and health impact mapping.

5.1.2 The need for environmental health hazard mapping

A clear need for environmental health hazard mapping exists in Africa, at international, national and local level. Potential users include international and inter-governmental organisations (e.g. WHO), national agencies with responsibility for environmental health (including ministries of health, ministries of environment, ministries of development) and regional/local authorities (including local government and health authorities). Amongst these organisations, environmental health hazard mapping can make a significant contribution towards a more preventive approach to environmental health problems, for example in the areas of:

- emergency preparedness and early warning of environmental hazards
- strategic environmental health assessment of policies, programmes and plans
- long-term planning for hazard prevention, mitigation and control
- awareness raising and community empowerment

In general, these applications are likely to be enhanced when health hazard mapping can be combined with information on the population at risk and the health impacts.

5.1.3 The capacity to undertake environmental health hazard

The capacity to undertake environmental health hazard mapping already exists in Africa, and is already being developed and applied in a number of areas. The capacity nevertheless varies greatly between countries. The main constraints relate to:

- the availability and quality of relevant data
- limitations of access to suitable mapping technologies within the relevant organisations
- limited availability of relevant expertise, especially within the relevant organisations
- limited financial resources – especially those needed to invest in the early development of mapping systems
- the existence of inappropriate attitudes to information and decision-making within the organisations concerned

5.1.4 Problems of data availability

Environmental health hazard mapping needs to rely on existing data for the most part; only limited scope will exist in most cases to collect new data. The existing data are, however, widely scattered in different agencies and sources, in different formats, and are of varied quality. Problems of access to these data, due to administrative difficulties and issues of confidentiality and cost are also often severe. Collation, integration and analysis of these data thus poses serious challenges. Progress will require active collaboration between the different organisations concerned. Strong motives for such collaboration can be adduced by emphasising the mutual benefits which can be gained, e.g.:

- by data sharing and exchange
- by sharing of expertise and mutual training and support
- by opportunities for cost sharing
- by the enhanced potential to bid for funding and support

One extremely and increasingly powerful source of data in this context is remote sensing. Action to improve access to, and interpret and analyse, remotely sensed data is thus an important priority.

5.1.5 The availability of relevant technologies

Modern computer mapping technologies offer powerful and effective methods for environmental health mapping. A wide range of such technologies now exist, and are increasingly being used in the area of environmental health. These include purpose designed systems such as EpiInfo and Healthmap, and proprietary GIS such as ArcView and MapInfo. Despite their higher cost and greater training needs, these proprietary GIS offer significant long-term advantages, especially in terms of:

- enhanced capability
- flexibility
- system support

Use of proprietary GIS can thus facilitate collaboration between different users with different needs, and allow for the inevitable evolution of these needs over time. They also make the exchange and combination of different data sets easier, and thus help to link hazard, population and health data. The use of simpler and cheaper systems, such as EpiInfo and Healthmap, compilable mapping tools (e.g. Proviewer or ArcExplorer) or low level entry mapping systems (e.g. MapMaker or Manifold) might be useful, however, to raise awareness about the potential for environmental health hazard mapping.

5.1.6 The availability of expertise

Expertise in the use of mapping methods is now widespread, and is increasing in Africa as elsewhere. To date, however, much of this expertise lies outside the health sector – for example, in academic, professional or private bodies concerned with geography, planning or environmental sciences. There is thus an important need to harness some of this expertise and transfer it to the health sector. This will be encouraged by greater multi-sectoral collaboration. It will also require opportunities for training of health-related professionals (e.g. by the provision of short training courses, or by including mapping methods in university courses).

5.1.7 The costs of establishing environmental health hazard mapping

In the long-term, environmental health hazard mapping promises significant financial, as well as social, savings: for example, by helping to prevent costly disasters, by reducing the need for health care, and by improving economic productivity and reducing production losses and associated costs. The long-term benefit-cost ratio of environmental health mapping is therefore likely to be positive; at worst it should be cost-neutral. Nevertheless, in the short-term, significant investment needs to be made to establish environmental health mapping systems. Typically, data collation and analysis make up the bulk of the costs involved in establishing mapping systems – often in a ratio of about four or five to one compared to costs of system purchase. If the principle of incremental development is adopted, however, data costs can be spread over many years, as new data are gradually added to what already exists. The main up-front costs are thus associated with purchase and maintenance of relevant mapping technologies and training of core staff. These costs will vary depending on the type of system and the number of users. Typically, however, it might be expected to amount to ca. US$10-20,000 to establish an operational GIS (including hardware, software, training and support). Thereafter costs of $2-5,000 per year might be envisaged for licence fees and maintenance. These short-term costs are likely to be a significant deterrent for many potential users. They can probably best be met if several users (perhaps in different sectors) are able to collaborate.

5.1.8 Development of strategic, information-based approaches to decision-making

Effective use of environmental health hazard mapping needs the existence of more than the data, technology and personnel. It also requires an information-based, forward-looking approach to decision-making. Where this exists, the potential of environmental health hazard mapping is likely to be readily apparent. Where it does not exist, the development and application of environmental health hazard mapping is liable to be retarded. Environmental health hazard mapping can, however, be a force for change in these circumstances: by showing how knowledge about the distribution of hazards can help to avert and mitigate their effects, it can highlight the benefits of more strategic ways of thinking. These benefits are likely to be most readily demonstrated in relation to acute environmental health hazards, and disasters, where the health effects are both immediate and apparent. The development of demonstration systems in relation to these hazards is therefore likely to be valuable.

5.1.9 Prioritising environmental health hazards

Once fully established, environmental health hazard mapping can be invaluable in helping to compare and prioritise environmental health hazards in a systematic way. At the outset, however, it is necessary to target the development of hazard mapping at a limited number of environmental health problems. These need to be selected and prioritised in consultation with the different parties concerned, including decision-makers and professionals in the environment, health and development fields. Important factors to consider in this process are:

- the extent, magnitude, frequency and duration of the hazards
- the number of people exposed to the hazards
- the susceptibility of those exposed
- the severity of the potential health effects
- the capability to avoid, manage or mitigate the hazard and its effects

5.1.10 The use of indicators

Indicators provide a useful and effective means of expressing environmental health hazards in ways which can easily be mapped and understood by the users. The development of indicators also helps to instil rigour into hazard mapping, by encouraging those concerned to think more deeply about the nature of the hazard and its potential health risks and effects. Indicators need to be developed to match the environmental health hazards of concern. Because these vary from one country (or one area) to another, the indicators, also, will need to differ; general-purpose indicators are likely to be of limited value. Equally, indicators need to vary depending on their specific purpose (e.g. whether to raise awareness, target action, or monitor effects of intervention). They thus need to be devised in close consultation with all the parties concerned, including (where relevant), members of the local community, professionals, and the media. The use of simple ‘systems analysis’ or ‘mind-maps’ can be extremely helpful in characterising the hazards and their effects, and identifying good indicators. Considerable benefits are also likely to be gained by comparing experience and pooling expertise. The production and dissemination of indicator lists and clear indicator profiles are valuable in this respect.

5.1.11 The multi-sectoral nature of environmental health hazards

Environmental health hazards are the concerns – directly or indirectly – of many different sectors at many different levels. Experience in hazard mapping, and the methods which this uses, is also widely scattered in different disciplines and professional areas. The health sector should logically provide the lead and co-ordination in environmental health hazard mapping, since the motive for action must derive from the risks to human health. The health sector, however, is often only weakly involved, and relatively poorly trained, in hazard mapping. There is consequently a need to encourage a more multi-sectoral and multi-disciplinary approach to the mapping and management of environmental health hazards, and to raise the level of understanding about these issues in the health sector.

5.1.12 Development pathways and strategies

Different approaches to the development of environmental health hazard mapping can be envisaged. These might be simply characterised as the 'top-down' or 'bottom-up' approaches. The former implies the development and agreement of standards and protocols for mapping (at national or international level) which can act as a framework for development; the latter implies encouragement of local systems, each customised to specific local needs. Each has its advantages and disadvantages, but the two do not need to be in opposition. Development will probably be most effective where local systems are encouraged and are then enabled and helped to come together and seek greater coherence within a broader federation of users. An important role of national or international/ intergovernmental bodies in this context is to provide guidelines and training, and to facilitate access to and sharing of data: all these will help to motivate collaboration and a more collective, multi-sectoral approach to development.

5.1.13 The need for awareness-raising and capacity building

There is an important need for both awareness raising and capacity building at the national and local level if environmental health hazard mapping is to be developed and applied successfully. This needs to cover almost all aspects of the hazard mapping process, including:

- the development of relevant methods and technologies
- data collection
- the design and construction of indicators
- the use of hazard information in decision-making

Training is an important part of this capacity building. Training needs to be aimed at:

- senior decision-makers and senior professionals to raise awareness about the potential value of environmental health hazard mapping and how it might contribute to planning
- at technical staff and more junior professionals to improve expertise in the techniques of environmental health hazard mapping

The development of expert networks is also important, since these can help to:

- encourage the sharing of expertise and experience
- encourage data sharing
- promote collaboration and sharing of facilities
- establish self-help groups

WHO-Afro has a clear and important role to play in capacity building, but other international and national organisations are also key players (e.g. UNDP, UNEP, UNICEF, World Bank, universities and GIS vendors).

5.2 Recommendations

WHO-Afro should take the lead in a five-pronged development programme, aimed at:

- raising awareness about the potential value of environmental health hazard mapping
- encouraging the sharing and exchange of experience
- fostering a multi-sectoral and cross-institutional approach
- building capacity and the national and local level
- developing standards, protocols and methods for environmental health hazard mapping

This strategy needs to recognise that different countries are likely to develop mapping systems at different rates. It should thus provide for local flexibility and should encourage mutual learning and support between countries. The main elements and timing of this strategy are summarised in Table 14.

Table 14. A timetable for action

Timescale (months)	Action	Description
0-3	Dissemination of this report	Circulation of report within WHO to raise awareness about EHHM
3	Internal working group on environmental health hazard mapping	Establishment of group of WHO-Afro to identify common interests, and agree on partners future actions and responsibilities
4-6	Establishment of national networks	Identification of focal points from relevant sectors (for dissemination/awareness raising)
4-12	Development project	Establishment and briefing of lead group; development of demonstration materials and indicators
6-9	Construction of Web site	Establishment of Web site with links to case studies, data sources, methods etc
9	International scientific workshop	Workshop to pool experience on EHHM across WHO and other agencies, universities etc and establish scientific basis for EHHM in Africa
6-12	Awareness-raising workshops/ seminars	Series of regional/national workshops aimed at key decision-makers and national experts
12-18	Development of expert network	Establishment of network of EHHM experts (Africa and overseas), as basis for exchange of experience and mutual support
12-24	Development of EHHM manual	Construction and publication of manual on EHHM methods
12 - 24	Staff development	Staff exchanges to share expertise and experience; organisation of short courses/seminars
12 - ….	Long-term capacity building	Development of software/methods (with GIS vendors etc); establishment of data networks; development of training courses

5.2.1 Dissemination of this report

Once approved, this report should be circulated within WHO-Afro and other WHO centres, with the request for further information on current interests in, and activities relating to, environmental health hazard mapping. Information gathered through this process should be used to help identify interested parties, and to establish an archive of relevant materials.

5.2.2 Internal working group on environmental health hazard mapping

Several divisions have interests in the development of environmental health hazard mapping, and the tools (e.g. indicators, GIS) which underlie this. Collaboration between different divisions within WHO-Afro should therefore be actively promoted, both to pool experience and funds. An inter-divisional working group should be established for this purpose, with the remit to explore ways of improving collaboration and sharing contacts with expertise in the member countries. Parties identified through circulation of this report should be amongst those invited.

Links with other programmes and developments in other regions (and at WHO-HQ) should also be explored, as should opportunities for linking environmental health hazard mapping into other mapping systems within WHO (e.g. EpiInfo, Healthmap).

5.2.3 Establishment of national and regional networks

In order to promote the concept of environmental health hazard mapping in the member countries, to gain from the experience which already exists there, and to encourage a multi-sectoral and cross-institutional approach to hazard mapping, networks should be established with decision-makers. These should provide a cascade of contacts between WHO, national organisations (e.g. relevant ministries, government agencies and universities) and regional/local authorities. Thus:

- WHO should identify focal points within the relevant national organisations, in the relevant sectors, in the member countries;
- working meetings should be held to exchange experience and establish a common understanding between these members;
- the focal points should be encouraged and supported to establish similar networks, within their own countries, with local and regional organisations;
- these networks should be used to identify and prioritise the environmental health hazards requiring specific attention in each country/region;
- over time, these networks should de developed to provide a mechanism for initiating environmental health hazard mapping in the member countries, and for formulating and disseminating common standards and protocols.

As far as possible, these networks should make use of, and link with, existing networks and contacts established by WHO-Afro (e.g. as part of initiatives on emergency preparedness). In general, representatives from the health sector (e.g. ministries of health) should be expected to lead these networks at the national and regional level, though other sectors may be more appropriate in some countries.

5.2.4 Development project

Nothing teaches like example, so awareness raising should be promoted through the development and dissemination of demonstration systems and case studies of environmental health hazard mapping. Several such examples exist (see Annex 1); the need is to collate and translate them into an instructive and accessible form. Others might readily be developed. WHO-Euro should establish a project to compile and make available these demonstration systems.

Some countries and some agencies (e.g. MARA) are already relatively well advanced in developing (and to a lesser extent using) environmental health hazard mapping. These can provide valuable testing grounds for mapping methods, and provide important models for others to follow. As part of this development project, therefore, WHO-Afro should seek to identify, bring-together and support a limited number of these agencies (perhaps 5-8 in the first instance) in order to establish a 'lead mapping group' within Africa.

5.2.5 Establishment of Web-site on environmental health hazard mapping and hazard mapping indicators

Because of the relatively thin spread of experience and expertise, and the large number of sectors that need to be involved, effective dissemination of the work on environmental health hazard mapping is essential. To this end, WHO-Afro should establish and maintain a Web-site on environmental health hazard mapping and environmental health hazard indicators (comparable to that on environmental health indicators already established on behalf of WHO-HQ – http://www.northampton.ac.uk/ncr/who/). The Web site should provide examples of environmental health hazard mapping, links to relevant projects, information on data sources and contacts, and prior announcements about training opportunities etc.

5.2.6 Scientific workshop on environmental health hazard mapping

Once the national networks have been established and demonstration materials have been compiled, a scientific workshop should be held on environmental hazard mapping. This should aim to bring together experts in environmental health hazard mapping from both within and outside Africa, national representatives from the wide range of relevant sectors concerned with environmental health hazards, and relevant professionals from WHO both in Africa and elsewhere. The workshop should provide demonstrations of environmental health hazard mapping, discuss and identify the hazards for which mapping needs to be developed, and establish scientific principles for environmental health hazard mapping within Africa.

5.2.7 Awareness-raising seminars

The scientific workshop should be followed by a series of awareness-raising seminars, to promote and demonstrate the concept of environmental health hazard mapping at the national and regional level. These meetings should be targeted at key decision-makers and potential users of environmental health hazard mapping, and co-ordinated through the national focal points.

5.2.8 Development of expert networks

In the long term, development of the capacity for environmental health hazard mapping is likely to come through self-help and sharing of experience within and between the member countries. Since this expertise is spread across different sectors (mainly outside health) and in different countries, this implies the need for effective networking between those concerned. WHO should encourage and facilitate the establishment of networks between relevant scientists, for example by developing and disseminating an 'address book' or directory of expertise, and by supporting study visits and mini-workshops in the member countries.

5.2.9 Development of an environmental health hazard mapping manual

To encourage and support development of environmental health hazard mapping at the local and national level, there is the need for a simple 'user manual'. The technical components of this report provide a starting point for such a manual; experience within the member states could greatly add to what is contained here. WHO-Afro should therefore commission further work to develop a manual on environmental health hazard mapping, with clear guidelines for different types of hazard (e.g. acute and chronic hazards) and for mapping at different scales (international, national, local).

5.2.10 Staff development

In the short term, limitations of both awareness and technical expertise are likely to be major constraints on the effective development and use of environmental health hazard mapping. Staff development and training are thus vital. WHO-Afro (together with WHO-HQ) should take a leading role in this development, for example by:

- sponsoring study visits and staff exchanges
- organising short courses and training sessions
- publicising opportunities for training (e.g. university-run courses)
- preparing and disseminating training materials (e.g. case studies)

5.2.11 Long term capacity building

Longer-term development of environmental health hazard mapping will require action on a number of fronts. Over the longer term, responsibility for development is also likely to devolve increasingly away from WHO to national and regional organisations, as they seek to develop their own systems. The role of WHO will thus become more one of co-ordination and dissemination. WHO-Afro (together with WHO-HQ, other WHO centres and partner agencies) should, however, take the lead in a number of long-term initiatives, for example:

- in negotiating with GIS-vendors/manufacturers to bundle relevant methods/models and data with their systems, and to offer favourable purchasing arrangements to member countries;
- by liaising with universities and other course providers to develop and market training programmes (e.g. MSc courses and short courses) aimed at environmental health hazard mapping;
- by consulting with member countries and international agencies to help establish data networks and encourage new, or more co-ordinated data gathering;
- by encouraging member countries to adopt a more information-based approach to environmental health (e.g. through the development and implementation of National Environmental Health Action Plans).

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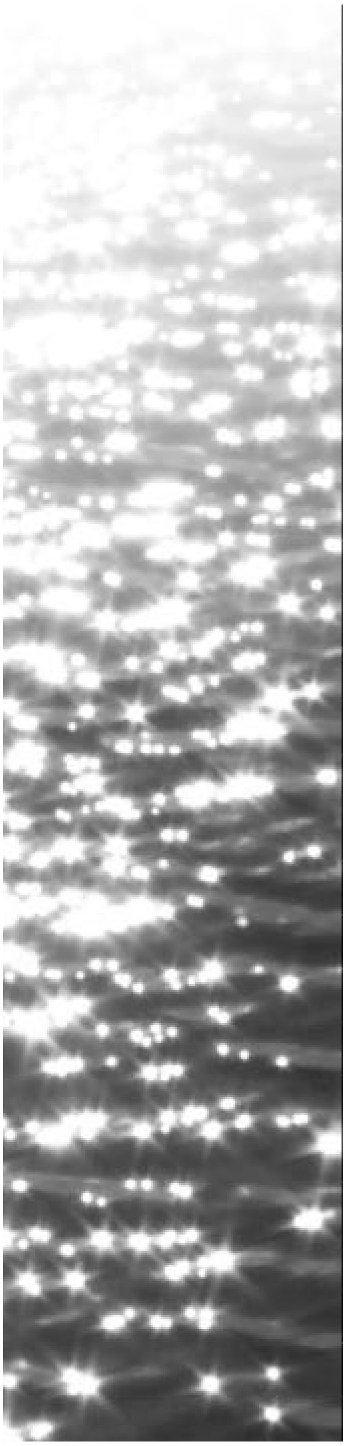
CASE STUDIES

Annex 1



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3.1 Malaria risk mapping in Africa

The Mapping Malaria Risk in Africa programme initiated to develop an atlas of malaria risk in Africa, as a basis for improving malaria management and control. The programme collects empirical data on the distribution of malaria, and uses GIS techniques to model and map the distribution of malaria risk. Disease incidence and mortality rates (i.e. health impact data) are preferred as a basis for mapping, since these describe the pattern of disease most directly. Many countries in Africa, however, do not have reliable disease surveillance systems, so other data are also used. These include:

- entomological inoculation rates (EIRs) – the number of infectious bites an individual is exposed to in a given period (e.g. a year); and
- parasite prevalence (or the parasite ratio) – the percentage of subjects found with a positive blood slide;

In addition, MARA carries out modelling to estimate the distribution of malaria, the number of people at risk, the level of risk, and the timing and duration of malaria transmission. Modelling is carried out at different spatial scales, from the continental to the local (ca. 30 km^2). At the continental scale, the most important variables are seen to be temperature (since this helps to determine both the duration of the cycle and the chance of vector survival) and rainfall (which also influences mosquito survival and abundance). The temperature limits for malaria transmission and vector survival were estimated to be between 18ºC and 32ºC, with a required rainfall level of 80 mm per month for at least 3-5 months. Data on these two variables are available at a resolution of about 5km^2, derived from weather stations and elevation data.

Figure A1 shows the climatic suitability for malaria based on this model, scaled from 0 (unsuitable for malaria) to 1 (highly suitable). The map clearly shows the broad zone across central Africa, within which malaria transmission is likely to be stable. In general terms, this map corresponds well to the distribution of historical malaria cases, in those areas where reliable data are available. Some discrepancies nevertheless occur, due to the local and regional influence of other factors, such as the availability of water bodies, which enhance survival.

By overlaying the map of climatic suitability onto population distribution, the number and distribution of people at risk can be estimated. Figure A2 shows the population density (in people per square kilometre, for 1990 data) in the area where the climate suitability is greater than 0.5. The core area of risk in central west Africa is clear. Based on this, an estimated 360 million people are seen to be at risk of infection. This translates into a potential mortality rate of between 305,000 and 683,000 (median 530,000).

These maps represent just two examples from the MARA Web site. Many other maps and examples can be found on http://www.mara.org.za/, in what is undoubtedly one of the best examples of environmental health hazard mapping in Africa.

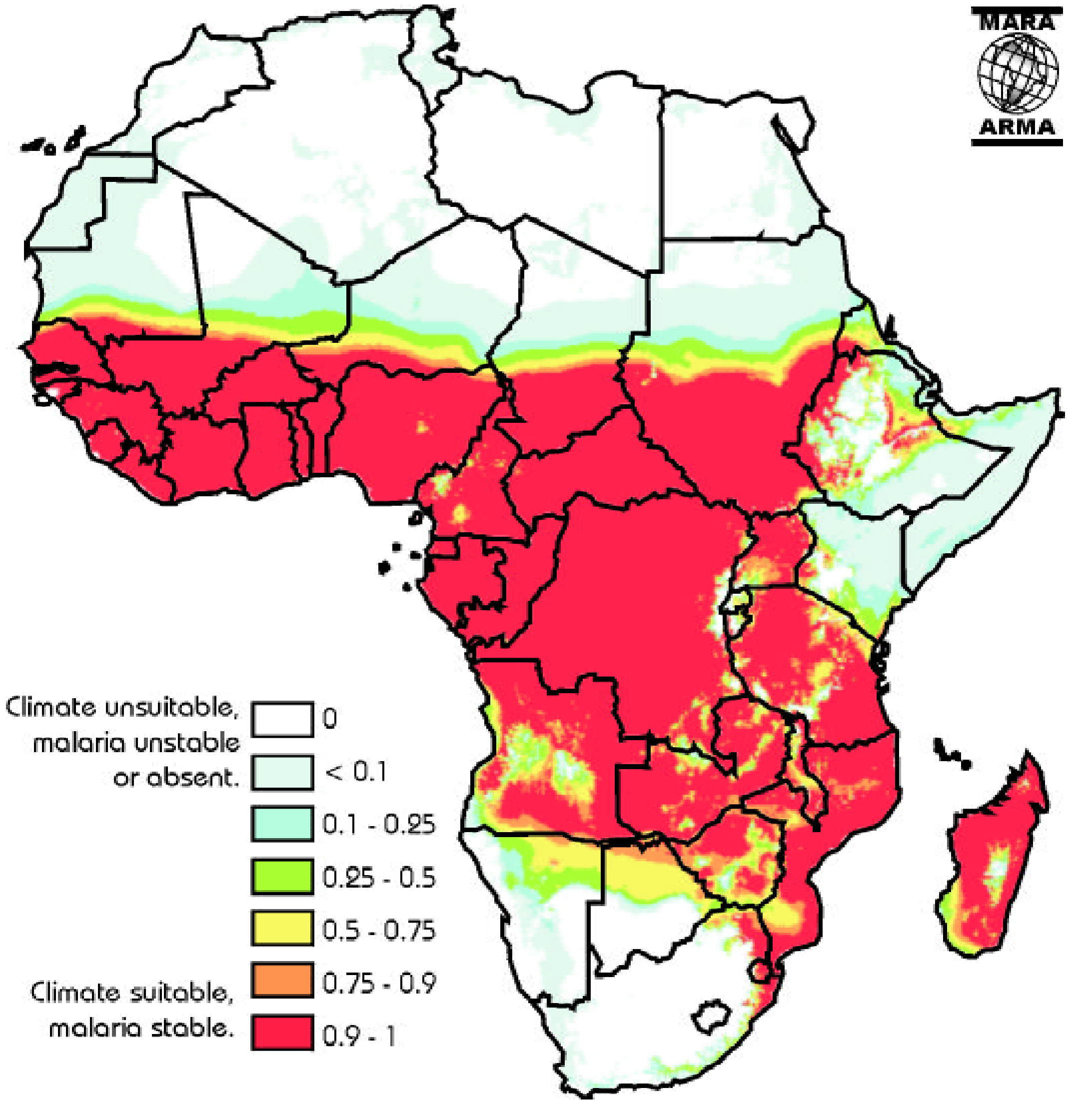


Figure A1. Climatic suitability for stable malaria transmission

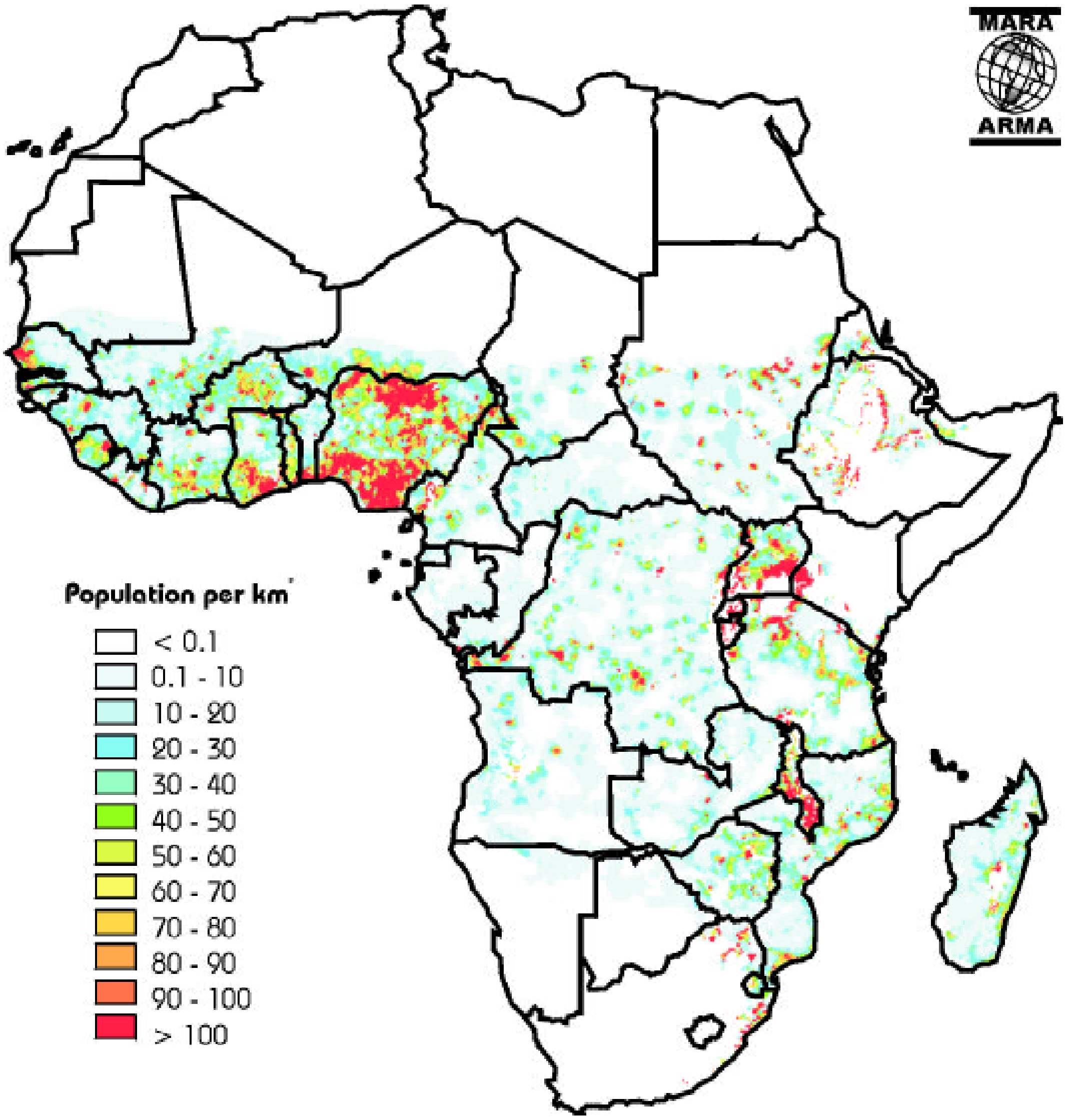


Figure A2. Population density in areas where malaria transmission is stable (climatic suitability > 0.5)

3.2 Mapping risk of river blindness in Central America

The Onchocerciasis Elimination Program for the Americas (OEPA) is a joint initiative between the Global 2000 River Blindness Program of the Carter Centre, the Pan American Health Organization and the ministries of health in six Central American countries. As part of this study a Regional Mapping Center was established at the Univesidad del Valle de Guatemala, with the remit to develop methods for mapping risks and prevalance of river blindness in the region.

River blindness (Onchocerciasis) is a parasitic disease caused by the filiarial worm *Onchocerca volvulus*. The vector for infection is a blackfly of the Simulium genus. The disease is endemic in six countries in the Americas (Brazil, Colombia, Ecuador, Guatemala, Mexico and Venezuela) and affects an estimated 131,000 people in 1,660 communities; about 1.6 million people are at risk.

The main risk factor for onchocercoma is the presence of the blackfly vector. The distribution of this is determined primarily by the availability of suitable breeding grounds – mainly in mountain streams. In order to model and map the population at risk, therefore, maps of the central study area in Guatemala were digitised, and all communities within the area georeferenced using GPS. Locations of potential breeding sites for the vector were defined on the maps, and a buffer of 5 km radius was then constructed around each breeding site, to represent the potential flight range of the fly.

Retrospective data on the distribution of onchocerciarsis for the previous ten years was also gathered by the Ministry of Health, and mapped by community. Overlaying the distribution of cases on the map of breeding sites shows that the large majority of hyper-endemic communities occur within the modelled flight zones around the breeding sites (Figure A3). Altitude is also an important risk factor for onchocerciarsis; when the distribution of sites was analysed in relation to height, it was seen that hyper- and meso-endemic communities were concentrated within a height range of 500 to 1500 metres. These maps thus help to identify the main areas of risk, and to target control programmes.

Based on results from the detailed study in Guatemala, regional mapping was carried out to identify suspect communities, plan the interbention programme, measure the performance of health workers and assess the impacts of treatment. Paper maps for each country were collated and digitised, communities were georeferenced and community data (on health and environmental conditions) were collected and incorporated into the GIS. This allowed thematic maps to be produced, showing for example the distribution of onchocerciarsis in relation to environmental factors (Figure A4). By providing the GIS to health workers, and by giving relevant training, field staff can also develop, update and validate maps based on their field results.

Further information on this study are available at http://www.esri.com/library/userconf/proc97/proc97/to200/pap182/p182.htm

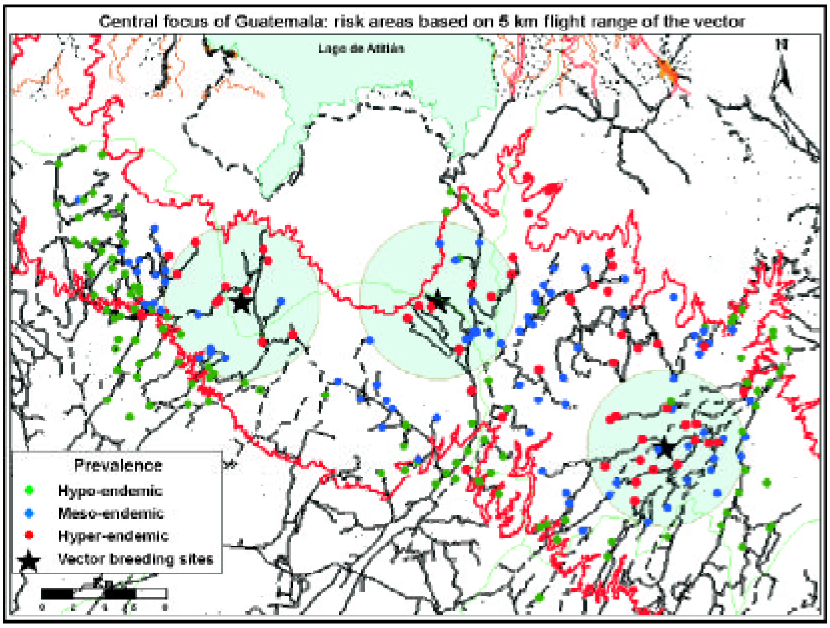


Figure A3. Onchocerciasis prevalence and risk zones in Guatemala

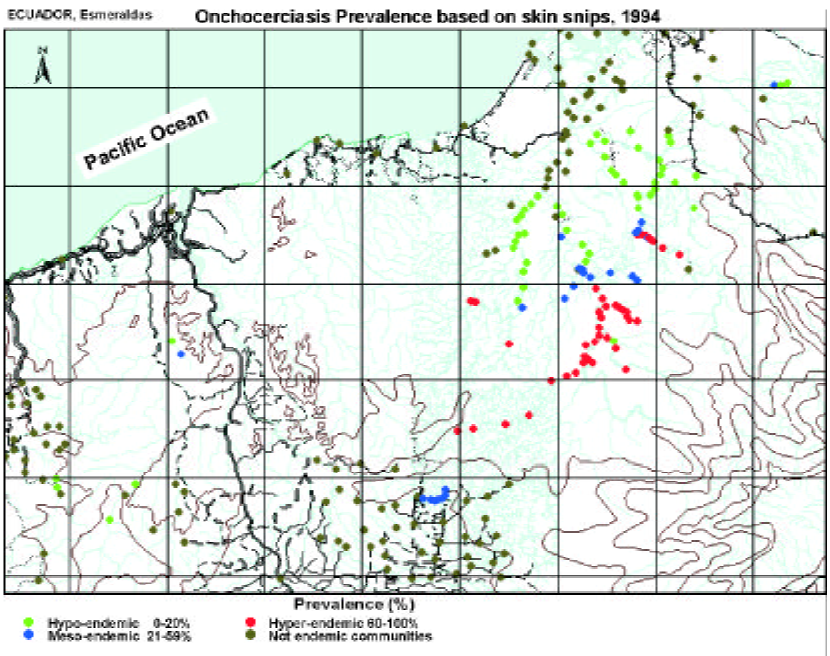


Figure A4. Onchocerciasis prevalence in Equador

3.3 Mapping natural hazards in the USA

Environmental health hazard mapping is especially well developed in the USA, where widespread availability of data and GIS technologies combine with serious public concerns about the health and economic costs of natural hazards. Major hazards include seismic activity, hurricanes, floods and avalanches. Hazard mapping is carried out by a range of agencies, including government bodies (e.g. USGS), state authorities and private institutions (e.g. insurance companies). Maps are also used for a wide variety of purposes, including emergency planning, development control, provision of early warnings to the public, and assessment of risk and liability.

3.4 Earthquake hazards

Figure A5 shows the distribution of seismic risks across the USA, produced by the USGS (http://geohazards.cr.usgs.gov/). The map is based on geological and seismic information, and shows the amount of horizontal shaking (expressed as the percentage of gravitational acceleration) which might be expected from earthquakes with a 10% probability over a ten year period. The main earthquake-active area in western USA is evident. More detailed maps are also produced at regional and state level, and for different probability and recurrence intervals.

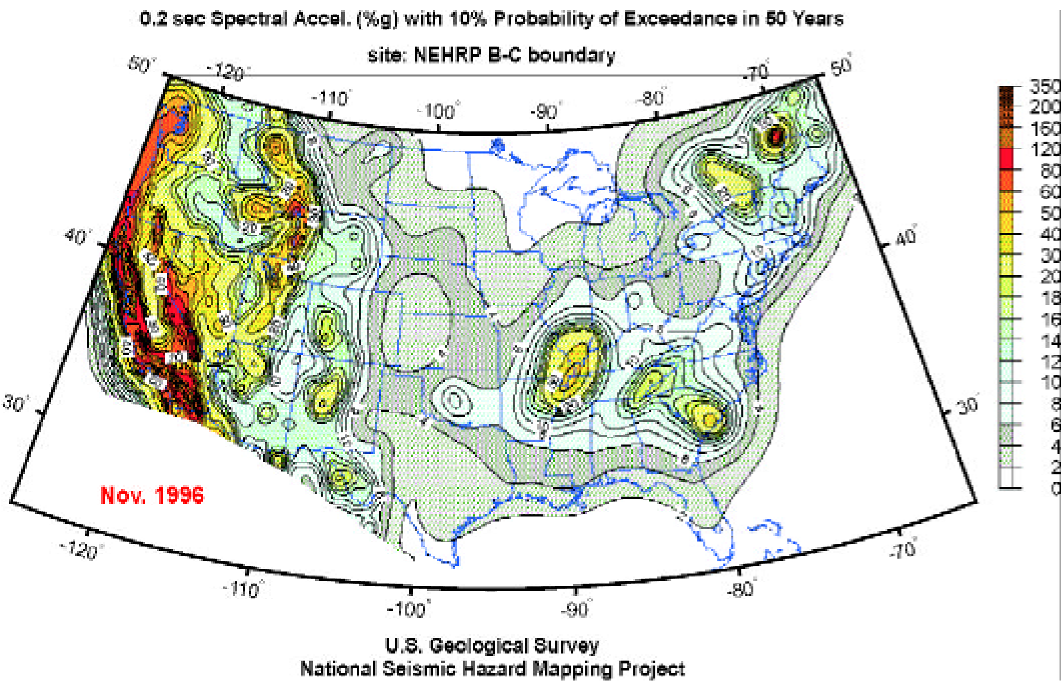
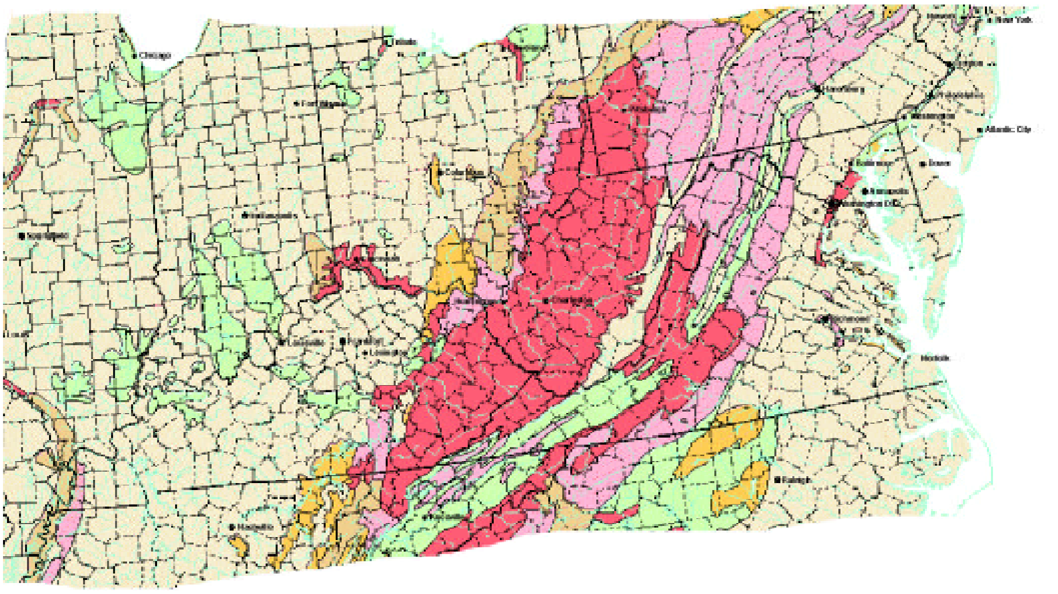


Figure A5 Earthquake hazards in the USA

The maps are used for a range of purposes, including to assess risks (e.g. by insurance companies), to help design buildings, to set building regulations, to develop emergency response plans, and plan and allocate emergency relief funds.

3.5 Landslide hazards

Figure A6 shows the distribution of landslide hazards in the eastern USA. The map shows two measures of the hazard: the landslide incidence (classified in terms of the percentage of the area involved) and the landslide susceptibility (the probable degree of response of the rocks to deep cutting or loading of slopes, or to extreme rainfall events. The maps are used for a range of purposes: for example to provide guidance to engineers on major construction projects, for planning and development control, and to assess and manage insurance risks.



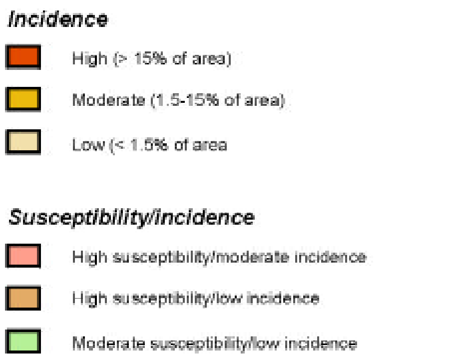


Figure A6. Landslide hazards in eastern USA

3.6 Flood hazards

Figure A6 shows a daily flood risk map for the USA. The map is based on flood forecasts made by thirteen Regional Flood Centres (RFCs) across the country. Forecasts are developed on the basis of data on rainfall, the water content of lying snow, antecedent river conditions, temperature, wind and evaporation rates. Hydrological models are used to predict likelihood of flooding, including flash floods, and are updated twice daily.

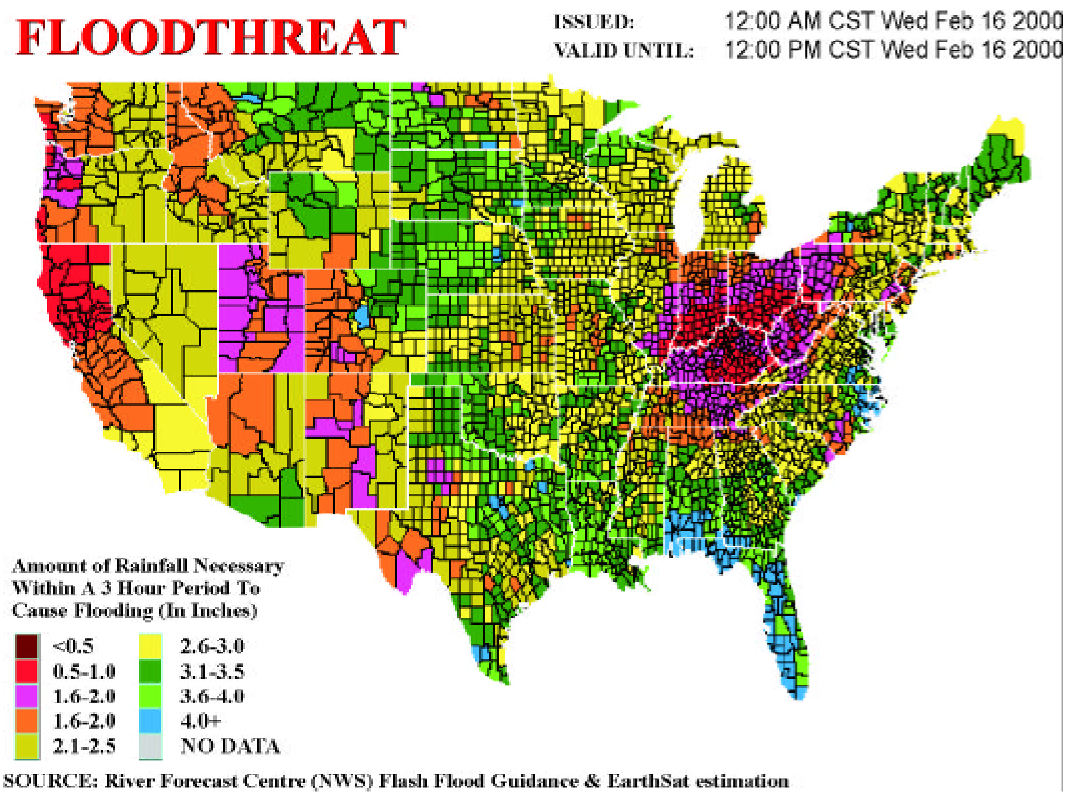


Figure A7. Flood risk is the USA

4. Environmental health hazard mapping for community awareness

Potentially one of the most influential uses of environmental health hazard mapping is to inform local communities, as a basis for enhancing public participation in environmental health protection. Two examples are shown here.

The first derives from the work of a community-based group: the Alaska Community Action on Toxics (ACAT). The group is dedicated to reducing the hazards of toxic substances in the environment, and to this end has compiled a number of databases on toxic sites, sources and releases in the state (e.g. hazardous chemicals, radioactive wastes and US Superfund sites). The maps are used to raise awareness in local communities and to lobby state and federal governments and industry. Figure A8 shows one example of the maps produced by ACAT (http://www.akaction.net/pages/mapping/). This relates to sites regarded as having potential risks of exposure to humans.

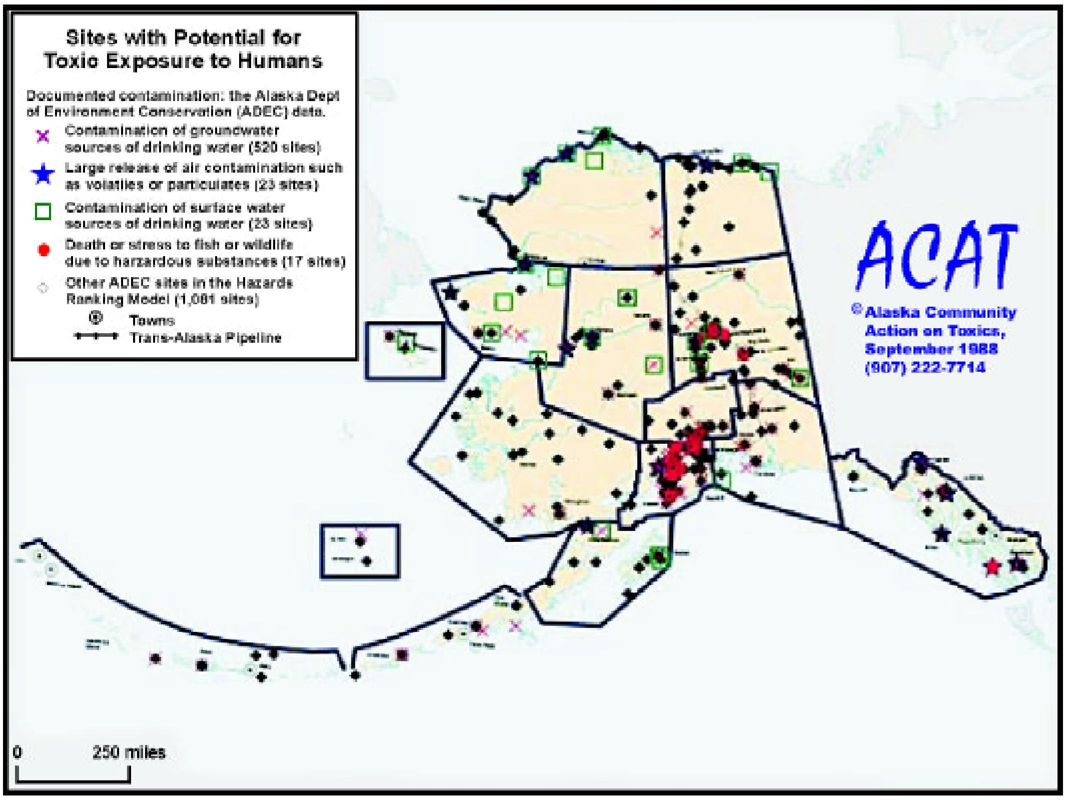


Figure A8. Sites with potential for toxic exposures to humans in Alaska

The second example (Figure A9) is derived from the work of FEMA (http://www.businessmap. com/data/online/ fema/femamaps.html). This produces flood risk maps at the community level, as a basis for screening property addresses or other locations for their flood prone status. Flood risk maps are held for about 1200 counties across the USA, and show the extent of Special Flood Hazard Areas – areas subject to inundation by the 100 year flood (i.e. with a 1% probability of flooding in any year). Users may create their own map, centred on a location of their choice.

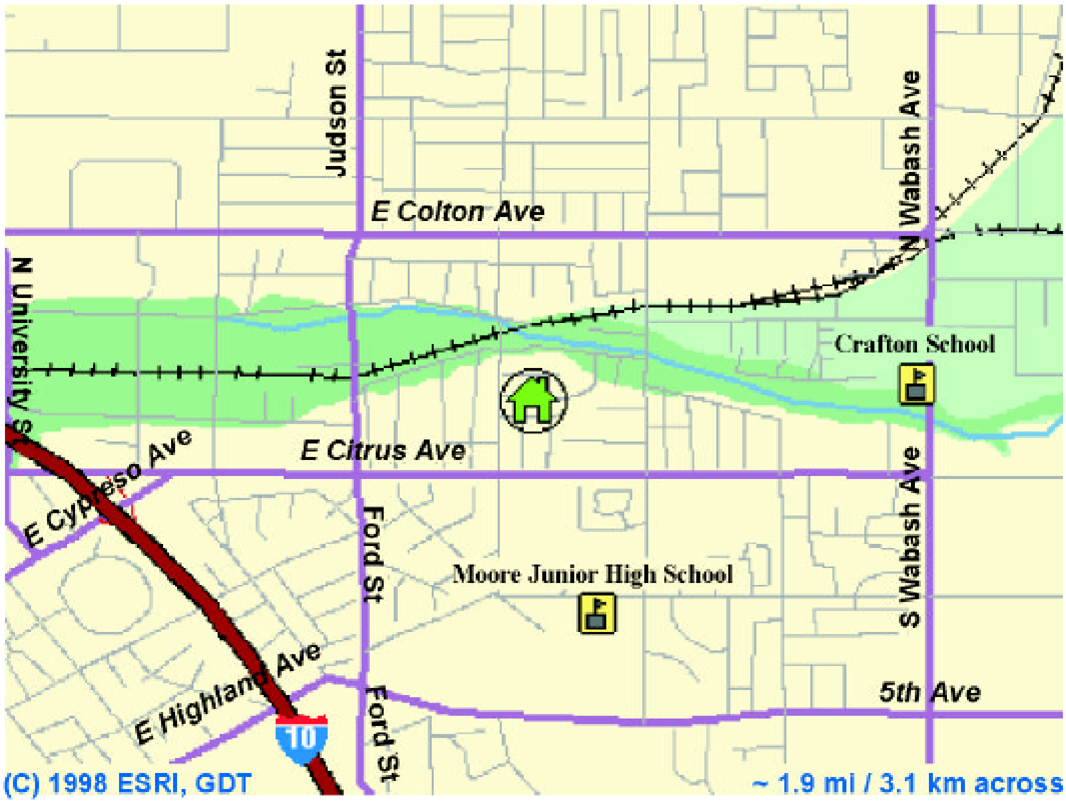


Figure A9. Community flood map

5.

Air pollution represents one of the most common hazards encountered by many people. Urban air pollution is also rising in many areas, as a result of increasing traffic volumes: health risks are therefore on the increase. In

target policy and plan traffic management, to monitor the effects of policy intervention, to raise awareness in the community, and to provide a basis for early warnings to those at risk.

Public Health (http://www.seiph.umds.ac.uk/envhealth/
both on data collated from monitoring sites in the city (using continuous monitors and passive samplers) and modelling techniques. Figure A10 shows the distribution of nitrogen dioxide in 1997. Maps are also produced

effects.

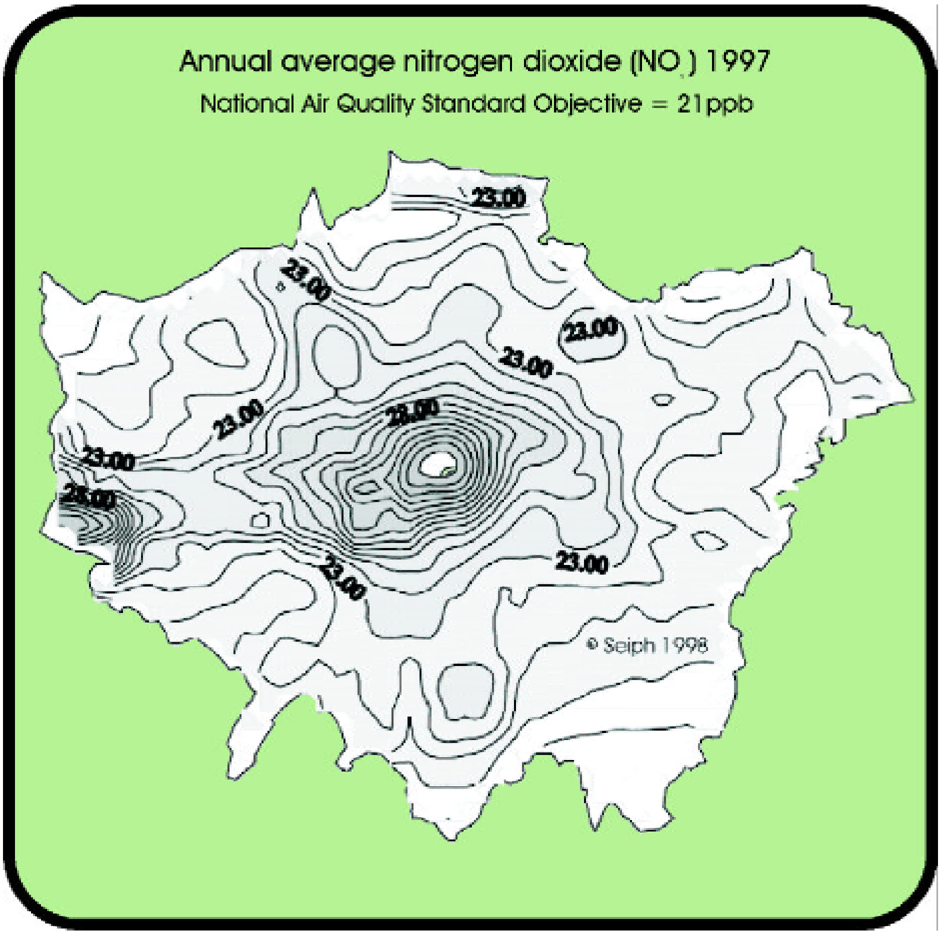
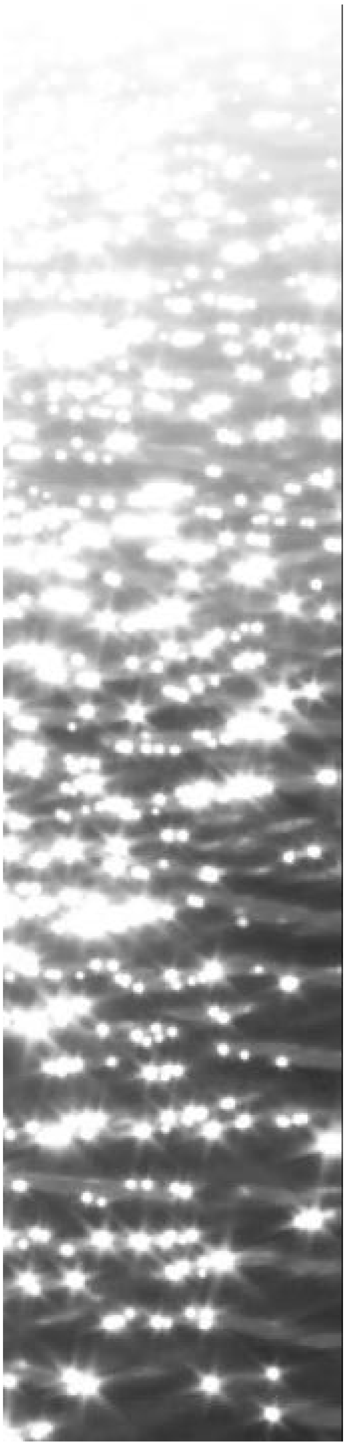


Figure A10. Nitrogen dioxide pollution in London

ENVIRONMENTAL HEALTH HAZARD INDICATORS

Annex 2



Introduction

This Annex provides examples of indicators which can be used for environmental health hazard mapping. As argued in the main body of the report, indicators need to be customised according to circumstance and need – the specific hazard of interest, the type of question being asked, the scale of analysis and the availability and quality of the data. For this reason, the emphasis here is not on providing a core set of environmental health hazard indicators, but on providing indicator profiles which show, for a sample of indicators, how they can be compiled and used.

Table A.1 repeats Table 8 from the main report: it provides a list of environmental health hazards and suggested indicators which might be used to map them. Indicators illustrated in the Annex are highlighted in bold.

The indicators listed in Table A.1 are classified into three types:

- *hazard indicators* – which define the hazard in terms of its extent, magnitude, duration, frequency or probability of occurrence, without reference either to the exposed population or health effect;
- *risk indicators* – which describe the hazard in terms of the number or percentage of people exposed;
- *health impact indicators* – which describe the hazard in terms of the actual health outcome, measured as either morbidity or mortality.

Which type of indicator is most appropriate is likely to depend on the specific question being asked. It is apparent, however, that different hazards are more-or-less amenable to description by these different types of indicator. Some, such as natural hazards, for example, can readily be described by hazard indicators. Others, such as suicides and domestic violence are more easily described by health impact indicators. Examples of all three types of indicator are presented in this Annex.

Table A2 explains the format of the indicator profiles. These are laid out in two sections: section one presents a generic explanation of the indicator, and gives background information (e.g. on the agencies involved, on examples of its use, and sources of further information). Section 2 gives a specific example of the indicator, showing how it can be constructed, the data required, and how it might be interpreted (including difficulties which might be encountered). These profiles – and indeed many of the indicators – are derived from the WHO website on environmental health indicators (http://www.northampton.ac.uk/ncr/who/).

Table A1. Examples of environmental health hazard indicators

Category	Hazard	Hazard indicator	Risk indicator	Health impact indicator
Land/climate-related hazards	Volcanic activity	**Area within 5 km of active volcanoes**	Number (or percentage) of people living within 5 km of active volcanoes	Number of deaths (or mortality rate) due to injury by volcanic activity
	Earthquakes	Area of recorded earthquake activity within living memory Frequency of earthquakes > 5 on the Richter scale Area with >10% probability of an earthquake > 5 on Richter scale within 100 years	Number (or percentage) of people living within	Number of deaths (or mortality rate) due to earthquake area
	Avalanches	Area of recorded avalanches in living memory Probability of avalanche in worst-case weather conditions	Number (or percentage) of people living within avalanche prone area	Number of deaths (or mortality rate) due to avalanches
	Flooding/storms	**Area within 100 year flood level** Flood probability	Number (or percentage) of people living within 100 year flood level	Number of deaths (or mortality rate) due to drowning

Table A1. Examples of environmental health hazard indicators

Category	Hazard	Hazard indicator	Risk indicator	Health impact indicator
Land/climate-hazards (continued)	Drought	Frequency of drought years Mean annual rainfall Mean annual precipitaion: evapotranspiration (P:E) ratio Area with >10% probability of drought	**Number (or percentage) of people living within area with a drought frequency of greater than 1 year in 10 years** Number (or percentage) of people living within areas with a P:E ratio < 0.75	Number of deaths (or related mortality rate) due to drought
	Hurricanes/wind	Hurricane frequency Area with >10% probability of hurricanes	Number (or percentage) of people living within area with a hurricane frequency greater than 1 in 10 years	Number of deaths (or mortality rate) due to hurricanes
	Soil erosion/ desertification	Area subject to severe soil erosion Mean annual soil erosion rate	Number (or percentage) of people living in area of severe soil erosion	
	UV radiation	**UV light index**	Number (or percentage) of people living in areas with a UV Index > 5	Annual incidence rate for skin cancers Standard mortality rate due to skin cancers
Atmospheric hazards	Outdoor air pollution	**Mean annual concentration of target air pollutants (e.g. SO_2, PM_{10}, NO_x, lead)** **Percentage of days on which air pollution levels exceed WHO guidelines**	Relative risk of respiratory illness due to air pollution	**Hospital admission rate for respiratory illness** **Percentage of children under 5 years of age suffering from upper respiratory tract illness**

Table A1. Examples of environmental health hazard indicators

Category	Hazard	Hazard indicator	Risk indicator	Health impact indicator
Water-related hazards	Surface water pollution	Mean annual concentration of target water pollutants (e.g. BOD, faecal coliforms) Length (or percentage) of streams classified as 'poor' quality		**Incidence of diarrhoeal morbidity in children under 5years of age** **Number of deaths (or mortality rate) due to diarrhoeal diseases in children under 5years of age** **Number of outbreaks of water-borne illness**
	Drinking water contamination	Percentage of drinking water samples failing drinking water standards	**Number (or percentage) of people reliant on contaminated drinking water** **Percentage of households (or population) served by untreated drinking water**	**Incidence of diarrhoeal morbidity in children under 5 years of age** **Number of deaths (or mortality rate) due to diarrhoeal diseases in children under 5 years of age** **Number of outbreaks of water-borne illness**
Food-borne hazards	Biological contamination	Percentage of food samples failing food quality standards due to biological contamination (e.g. *Salmonella*, *E. coli*, *Campolybacter)*		Number of outbreaks of food-borne illnesses Number of deaths (or mortality rate) due to food-borne illnesses
	Chemical contamination	Percentage of food samples failing food quality standards due to chemical contamination (e.g. pesticides)		

Table A1. Examples of environmental health hazard indicators

Category	Hazard	Hazard indicator	Risk indicator	Health impact indicator
Vector-borne hazards	Water-related vectors	Number (or population density) of water-borne parasites Percentage of water-bodies infected with disease vectors Area of potential breeding grounds for water-borne vectors	**Number (or percentage) of people living in areas in which water-related disease vectors are endemic**	Prevalence of water-related infections (e.g. of schistosomiasis, dracunculiasis, malaria) **Number of deaths (or mortality rate) due to water-related infections (e.g. of schistosomiasis, dracunculiasis, malaria)**
	Animal-related vectors	Number (or population density) of animal-carriers (e.g. rats) Area of potential breeding grounds for animal-related vectors	**Number (or percentage) of people living in areas in which animal-related disease vectors are endemic**	Prevalence of animal-related infections (e.g. sleeping sickness, bubonic plague) **Number of deaths (or mortality rate) due to animal-related vectors (e.g. bubonic plague)**
Domestic hazards	Indoor air pollution	Mean annual concentration of target pollutants (e.g. CO, NO_2, particulates) in domestic premises	**Number (or percentage) of peoplereliant on kerosene, wood, dung or open coal fires for cooking/heating**	**Hospital admission rate for respiratory illness** **Percentage of children under 5 years of age suffering from upper respiratory tract illness**
	Domestic accidents		**Percentage of people living in inadequate or unsafe housing**	**Hospital admission rate for domestic injuries** Number of deaths (or mortality rate) due to domestic injuries

Table A1. Examples of environmental health hazard indicators

Category	Hazard	Hazard indicator	Risk indicator	Health impact indicator
Domestic hazards (continued)	Domestic violence		Number of reported cases of domestic violence	Hospital admission rate for injury by domestic violence Number of deaths (or mortality rate) due to domestic violence
	Suicide			Hospital admission rate for attempted suicide Number of deaths (or mortality rate) due to suicide
	Sanitation		**Percentage of households (or population) not connected to sanitation services**	
	Waste handling	**Percentage of waste safely disposed by municipal waste services (e.g. by contained landfill, incineration)** Area of unsealed waste sites	**Percentage of households not served by regular waste collection service**	Prevalence of waste-related infections (e.g. bubonic plague, (endemic typhus, leptospirosis) Number of deaths (or mortality rate) due to waste-related infections (e.g. bubonic plague, endemic typhus, leptospirosis)
Occupational hazards	Industrial pollutants		**Number (or percentage of workers) employed in hazardous or unregulated industries**	Hospital admission rate due to acute occupational exposures Number of deaths (or mortality rate) due to acute occupational exposures

Table A1. Examples of environmental health hazard indicators

Occupational hazards (continued)	Occupational accidents		**Number (or percentage) or workers employed in hazardous or unregulated industries**	**Hospital admission rate due to occupational injury**
				Number of deaths (or mortality rate) due to occupational injury
Infrastructural hazards	Traffic accidents	Average traffic speed in built-up areas Vehicle energy index (speed x number of vehicles) in built-up areas	Number of reported traffic accidents	Hospital admission rate due to traffic accidents **Number of deaths (or mortality rate) due to traffic accidents**
	Industrial accidents		Number (or percentage) of people living within 1 km of hazardous industrial plants Number of reported industrial accidents (e.g. fires, release of hazardous substances, explosions)	Number of deaths (or mortality rate) due to industrial accidents
	Contaminated land	Area of contaminated land Area of unsealed waste sites	Number (or percentage) of people living on contaminated sites (including waste sites)	

Table A2. Key to indicator profiles

Brief title of indicator	Type of indicator
INDICATOR PROFILE	
Hazard	Specification of the environmental health hazard(s) to which the indicator relates
Rationale and role	Outline of the justification for the indicator and its potential use in relation to the hazard(s) specified. Where appropriate, indicates the main user communities and the level of aggregation/geographic scale at which the indicator might be used.
Alternative methods and definitions	Outlines possible alternatives to, or variations on, the indicator. In particular, suggests how the indicator can be improved (where suitable data exist), or adjusted/simplified to cope with inadequacies in the available data. If appropriate, suggests proxy indicators.
Related indicator sets	Lists similar or related indicators, proposed or developed as part of other indicator sets (e.g. UN Indicators for sustainable development, UNCHS Urban indicators programme, WHO Catalogue of health indicators)
Sources of further information	Gives full details of references and other sources of information relevant to the indicator (e.g. Web addresses, databases). Lists, in particular, references to other indicator sets using similar indicators, examples of the use of the indicator, or materials which describe the context and rationale for its use.
Involved agencies	Lists agencies which have a leading role in relation to the indicator, including: data providers, indicator developers, indicator users. Includes international, national and - where relevant - regional/local agencies.
EXAMPLE INDICATOR	
Definition of indicator	Detailed definition of the indicator
Underlying definitions and concepts	Definition of all terms and concepts involved in describing and constructing the indicator.
Specification of data needed	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).
Computation	Specifies the way in which the indicator is computed: i.e. how the data are analysed/ 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
Scale of application	Specifies the potential scales of application or level of aggregation. Note that the scale specified refers to the area across which the indicator can be used; for geographic comparisons, the indicator might be developed at lower levels of aggregation. Definitions: local (within a city or community); regional (within a sub-national region); national (for a country); international (across several countries or globally).
Interpretation	Describes the ways in which the indicator may be interpreted in relation to the hazard(s) specified. 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.

EXTENT OF VOLCANIC - PRONE AREAS	HAZARD
INDICATOR PROFILE	
Hazard	Volcanic activity
Rationale and role	Volcanoes are a significant source of injury and death in some areas, both as a result of the direct effects of exposure to lava, dust and hot or toxic gases, and because of the indirect effects of volcanic fall-out on crops, water supplies and livelihoods. This indicator provides a measure of the extent of this hazard. As such, it can be used to: • define volcanic-prone areas and help identify the populations at risk • show where early warning systems and emergency procedures need to be developed and implemented • help to plan the allocation of emergency relief funds and other resources
Alternative methods and definitions	Volcanic haza rds may be measured and mapped in a variety of different ways (see Table A2): for example in terms of the area of volcanic activity, the frequency of volcanic activity, the population living within volcanic-prone areas, or the reported number of injuries or deaths due to volcanic activity.
Related indicator sets	UN System-Wide Earthwatch *Island indicators* • Threat
Sources of further information	Berger, A.R. 1997. Assessing rapid environmental change using geoindicators. *Environmental Geology* 29
Involved agencies	National geological and seismological institutes WHO-Afro Emergency and Humanitarian Action Unit
EXAMPLE INDICATOR	
Definition of indicator	Area within 5 km of active volcanoes
Underlying definitions and concepts	Active volcano: a volcano known from seismic or historic observation to be liable to erupt within a specified period (e.g. 50 or 100 years).
Specification of data needed	Location of active volcanoes
Data sources, availability and quality	Data on active volcanoes are generally available from geological services and existing maps. Remote sensing (including thermal imagery) also provides a useful source of data in remote areas.
Computation	Computed by buffering around the centre of known active earthquakes; the area within the buffer zone (discounting overlaps) is then measured.
Units of measurement	Km2
Scale of application	Local to international
Interpretation	This indicator provides a simple measure of the extent of th e hazard from active volcanoes. It fails, however, to distinguish the magnitude of this hazard, either in terms of the type (and scale) of the eruptions, or their frequency. As a hazard indicator, it also takes no account of the number of people exposed, or their level of preparedness.

EXTENT OF EXTREME FLOOD EVENTS	HAZARD
INDICATOR PROFILE	
Hazard	Flooding/storms
Rationale and role	Floods and inundations caused by extreme weather events are a major source of death and injury, both in river and coastal areas. Health effects occur both because of the direct effects of injury and drowning, and the longer-term effects of resulting pollution and contamination of water supplies, damage to crops, and exposure to the elements and disease. This indicator provides a measure of the extent of this hazard, and can be used: • to define the flood-prone area and the population likely to be at risk • to identify areas where special planning or building regulations need to be enforced (e.g. to restrict development or set minimum standards for flood-proofing) • to assess insurance risks and liabilities • to advise the public on the risks they face and encourage appropriate protection (e.g. insurance, flood-proofing of homes) • to plan and prepare emergency response measures
Alternative methods and definitions	The extent of extreme flood events can be defined by mapping the areA likely to be inundated by floods of a specified magnitude or return period (e.g. the 100 year flood). This can be based either on topographic and weather information, or on records of past flood events. Alternatively, the indicator could be measured in terms of the flood frequency or probability (e.g. the number of years in any hundred when flooding might be expected to occur), the population living within the flood-prone area, or the number of deaths and/or injuries attributable to floods. For advance warning of riverine floods, a useful indicator is the amount of rainfall needed within a specified time to cause flooding.
Related indicator sets	
Sources of further information	USGS FEWS Flood risk monitoring in East Africa (http://edcsnw4.cr.usgs.gov/ip/fewsfloodrisk/)
Involved agencies	National weather bureaux and hydrological institutes World Meteorological Office WHO-Afro Emergency and Humanitarian Action Unit International aid agencies
EXAMPLE INDICATOR	
Definition of indicator	The area of land lying below the level of the 100 year flood
Underlying definitions and concepts	100 year flood: a flood event with an expected return period of once in 100 years
Specification of data needed	Magnitude-frequency data on flood events
Data sources, availability and quality	Data on the extent of the 100 year flood may be available from existing maps compiled by meteorological or hydrological institutes. Alternatively, the extent of the flood-prone area may be estimated by extrapolation either from data on stream discharge and depth (i.e. by computing the magnitude-frequency relationship and translating this onto topographic maps) or by extrapolation from historic records of floods.
Computation	Maps of the 100 year flood extent can be drawn and the area within the flood limits measured.

Units of measuremnet	Km^2
Scale of application	Local to international
Interpretation	This indicator provides a direct and simple measure of the extent of flood risk. It needs to be interpreted with care, however, both because of possible uncertainties in the estimates of the flood extent, and because – like all hazard indicators – it takes no account of the population distribution and thus the number of people at risk. Differences in emergency preparedness are also important in determining the health effects of any flood event. In addition, it needs to be remembered that extreme flood events do not occur at regular intervals (i.e. 100 year floods do not occur 100 years apart). Indeed, most floods show some degree of clustering, as a result of the 'locking' of the climate into specific weather patterns.

POPULATION LIVING IN DROUGHT-PRONE AREAS	RISK
INDICATOR PROFILE	
Hazard	Drought
Rationale and role	Drought has an all-pervading and long-term effect on human health. Shortage of water not only affects health status directly (e.g. by causing dehydration), but also has far-reaching effects on crop growth, livestock survival and economic viability. These effects are often long-lasting, since crop failure in one year may mean lack of seed for plating is subsequent years, the loss of livestock or lack of income to maintain farms rents etc. Water shortages are also associated with increased contamination of water supplies, both because of lack of dilution of pollutants, and because of the increased tendency for humans and animals to share the available water supplies. Impaired hygiene can add to the disease burden. This indicator provides a measure of the population at risk from drought. It can be used to: • identify drought risk areas and vulnerable populations • target and plan preventive measures (e.g. to improve water storage and supply) • plan and prepare emergency relief and disaster management measures • plan and allocate relief funding • raise awareness in the local community about drought hazards and possible preventive measures • assess insurance risks and liabilities • model and assess the possible effects of intervention, or changes in policy or land management
Alternative methods and definitions	The extent of the population living within drought-prone areas can be defined in a number of ways. For many applications, a local definition of 'drought' is best used, since this takes account of the impact of water shortage on the communities concerned (e.g. depending on their lifestyle, level of development etc). Where the need is to make broad-scale or international comparisons, however, a more explicit and consistent definition of drought may need to be used – based, perhaps, on the rainfall level relative to the long-term mean, or the preciptation:evapotranspiration (P:E) ratio. In either case, it will usually be necessary to define a threshold frequency or probability (e.g. one year in ten) for the recurrence of drought events, in order to define the drought-prone area. Alternatively, the drought probability may itself be mapped. Another alternative is to map the rainfall amount (e.g. as the mean annual rainfall, average dry-season rainfall or mean rainfall during the growing season), or the P:E ratio. Such measures, however, do not take account of the variability of rainfall – one of the main factors in determining the frequency and intensity of drought.
Related indicator sets	UN Indicators of sustainable development • Land affected by desertification • National monthly rainfall index UN System-Wide Earthwatch Island indicators • Threat
Sources of further information	Hambly, H. and Onweng Angura, T. 1996 Grassroots indicators for desertification. Experience and perspectives from Eastern and Southern Africa. IRDC (http://www.idrc.ca/books/focus/794/index.html)
Involved agencies	National meteorological offices World Meteorological Office WHO-Afro – Emergency and Humanitarian Action Unit FAO

EXAMPLE INDICATOR	
Definition of indicator	Percentage of the population living in areas with a drought probability of greater than 10%
Underlying definitions and concepts	**Drought**: a year (or other period – e.g. planting season) during which the total rainfall falls below a specified threshold (measured either as a percentage of the long-term mean, or a minimum amount estimated to be required for adequate crop growth and human consumption). **Drought probability**: the average number of years per hundred in which the specified drought conditions may be expected to occur. **Population living within drought-prone area**: the percentage of the total resident population who live within the area defined as drought-prone.
Specification of data needed	Drought frequency Total resident population
Data sources, availability and quality	Data on drought frequency may be obtained either directly from meteorological services, or by analysis of meteorological data. These data are liable to be subject to some uncertainty, both because of the limited distribution of climatic monitoring stations, and the problems inherent in estimating drought recurrence intervals. Data on the total population can be obtained from national censuses and should be reasonably reliable (except in more remote areas).
Computation	The area defined as having a drought probability equal to or greater than the specified threshold (e.g. 10%) is mapped. The population living within this area is then computed, either by map overlay. $Rd = Pd / Pt$ where Rd is the percentage of the population at risk of drought; Pd is the number of people living within the drought-prone area; Pt is the total resident population
Units of measurement	Percentage
Scale of application	Local to international
Interpretation	This indicator provides a useful means of mapping and comparing the population at risk from drought. An increase in the number of people classified as living in drought-prone areas may be interpreted as evidence of an increased risk. The indicator does, however, need to be interpreted with caution. The use of a threshold probability to define the drought-prone area, for example, means that it fails to distinguish between areas which differ in terms of their drought frequency, above this threshold. It also takes no account of the intensity of the droughts (all droughts are treated as equal). In addition, the indicator assumes that simply living within the drought-prone area represents a condition of risk: in practice, the level at risk varies depending on the lifestyle, occupation and social status of those concerned, and on their (and the government's) level of preparedness to deal with drought events.

UV LIGHT INDEX	HAZARD
INDICATOR PROFILE	
Hazard	UV radiation
Rationale and role	Exposures to excessive levels of solar radiation can pose serious risks to health. Adverse health effects include non-melanoma skin cancer, eye damage (including cataracts) and possible deleterious effects on the immune system. In the context of ozone depletion, global climate change and more extensive holiday travel, solar radiation thus represents an increasingly important source of health risk. This indicator is intended to provide a measure of potentially adverse exposures to ultra-violet radiation. It may be used to: • assess levels of exposure across the population - e.g. to help identify those most at risk of deleterious health effects; • raise public awareness about the potential risks of exposures to solar radiation; • monitor the effectiveness of public information and other campaigns, aimed at reducing exposures; • provide an early warning of excess exposures to those most at risk; • help develop and promote standards for protection against UV radiation; • help analyse relationships between exposure to solar radiation and health outcome.
Alternative methods and definitions	This indicator needs to define the amount of short-wave, ultra-violet radiation from the sun which reaches the ground surface. One useful approach to this is provided by the UV light index (ICNIRP 1995), which is a time-integrated measure of UV radiation. Several variations on this index are available, for example using different action spectra or different methods for integrating measured irradiation over time. Several different scaling systems have also been devised, to convert the resultant values into a simple measure of health risk (e.g. the minimum erythema dose, MED).
Related indicator sets	None
Sources of further information	ICNIRP 1995 Global solar UV index. Oberschleissheim: ICNIRP.
Involved agencies	WHO-Afro WMO International Commission on Non-Ionizing Radiation Protection (ICNIRP)
EXAMPLE INDICATOR	
Definition of indicator	UV light index
Underlying definitions and concepts	**UV light index:** a time-integrated measure of the amount of short wave, ultra-violet radiation from the sun which reaches the ground. **Weighted irradiance:** a measure of the solar radiation, defined as the weighed integral of the spectral radiance over direction and wavelength at ground level. This is based on the CIE erythemal action spectrum.
Specification of data needed	Weighted irradiance
Data sources, availability and quality	Data on levels of UV radiation are generally available from national meteorological services, and may be considered reliable. Monitoring networks are, however, often sparse, so they may be unable to detect local variations in UV levels.

Computation	The indicator is based on the Global solar UV index (ICNIRP 1995). It is computed as:
	$I_t * 40$ where I_t is the time-weighted average effective irradiance (W/m^2).
Units of measurement	W/m^2
Scale of application	Regional to international
Interpretation	This indicator provides a direct measure of the levels of exposure to UV radiation: the higher the index, the greater the level of exposure and the greater the potential risk of adverse health effects. The relationship between levels of UV radiation and health outcome are, however, complex: they are fundamentally affected by lifestyle and behavioural factors, such as time spent outdoors, choice of clothing and use of UV protection. Skin colour is also important.

AMBIENT CONCENTRATIONS OF AIR POLLUTANTS IN URBAN AREAS	HAZARD
INDICATOR PROFILE	
Hazard	Outdoor air pollution Indoor air pollution
Rationale and role	This indicator provides a measure of the hazard associated with ambient air pollution. It thus provides an indirect measure of population exposure to air pollution in urban areas. The indicator may be used: • to monitor trends in air pollution as a basis for prioritising policy actions; • to map levels of air pollution in order to identify hotspots or areas in need of special action; • to help assess the number of people exposed to excess levels of air pollution; • to monitor levels of compliance with air quality standards; • to assess the effects of air quality policies; • to help investigate associations between air pollution and health effects.
Alternative methods and definitions	This indicator may be designed and constructed in a number of ways. Where monitored data are available, it might usefully be expressed in terms of mean annual or percentile concentrations of air pollutants with known health effects - e.g. ozone, CO, particulates (PM_{10}, $PM_{2.5}$, SPM), black smoke, SO_2, NO_2, O_3, VOCs, benzene and lead - in the outdoor air in urban areas. Alternatively, the indicator might be expressed in terms of the number of days on which air quality guidelines or standards are exceeded (though in this case comparisons need to be made with care because of possible changes or differences in the guideline values). Where monitoring data are unavailable, estimates of pollution levels may be made using air pollution models. Dispersion models are, however, depend on the availability of emissions data; where these are not available, surveys may be conducted using rapid source inventory techniques (Economopolous 1993). Because of potential errors in the models or the input data, results from dispersion models should ideally be validated against monitored data.
Related indicator sets	UN *Indicators of sustainable development* • Ambient concentrations of pollutants in urban areas
Sources of further information	Economopolous, A.P. 1993 *Assessment of sources of air, water and land pollution.* A guide to rapid source inventory techniques and their use in formulating environmental control strategies, (2 vols). Geneva: WHO. UN 1996 *Indicators of Sustainable Development: framework and methodologies.* Report for the UN Commission on Sustainable Development. New York: UN Department for Policy Coordination and Sustainable Development. WHO 1987 *Air Quality Guidelines for Europe.* WHO Regional Publications, European Series No. 23. Geneva: WHO. (updated 1998: see http://www.who.int). WHO 1998 Healthy Cities Air Management Information System AMIS 2.0. CDRom. Geneva: WHO.
Involved agencies	WHO-Programme for the Promotion of Environmental Health National air quality monitoring networks WHO European Centre for Environment and Health European Environment Agency and Air Quality Topic Centre
EXAMPLE INDICATOR	
Definition of indicator	Mean annual and percentile concentrations of ozone, CO, particulates (PM_{10}, $PM_{2.5}$, SPM), SO_2, NO_2, O_3 and lead in the outdoor air in urban areas.

Underlying definitions and concepts	This indicator is based on the assumption that outdoor levels of air pollution in urban areas represent a significant source of exposure and health risk. Underlying definitions are: • **Mean annual concentration**: mean concentration of the pollutant of concern, averaged over all hours of the year. • **Percentile concentration**: concentration of pollutant of concern exceeded in 100-X% of hours, where X is the percentile as defined by the relevant standards.
Specification of data needed	Mean annual and percentile concentrations for CO, PM_{10}, $PM_{2.5}$, SPM, SO_2, NO_2, O_3 and lead. Site location, site type (e.g. kerbside, intermediate, background), monitoring method (e.g. passive sampler, continuous monitor) and sampling frequency.
Data sources, availability and quality	Data on ambient air pollution concentrations can be obtained from national or local monitoring networks, using either continuous (fixed-site) monitors or passive samplers. In addition, a growing volume of data can be obtained from the WHO Healthy Cities Air Management Information System (AMIS).
Computation	The indicator can be presented as: • the mean annual concentration • the relevant (e.g. 98th) percentile concentration or otherwise as appropriate (e.g. number of days/hours in excess of air pollution standard).
Units of measurement	$\mu g/m^3$, ppm or ppb, as appropriate; or percentage of days when standards/guideline values are exceeded.
Scale of application	Mainly local to regional; application at broader scales is limited by the spatial non-representativeness of monitoring stations.
Interpretation	This indicator can be used to interpret both spatial patterns and temporal trends in air pollution levels. In general terms, an increase in pollutant concentrations may be taken to suggest an increase in exposures and raised health risk; a reduction in pollution levels implies a decrease in exposures and a reduction in health risk. Interpretation is often aided by reference to the relevant air quality guidelines or standards (e.g. by assessing the number of days or hours during which the standards are exceeded). Several factors nevertheless need to be taken into account in interpretation. One of the most important is the siting of the monitors. As a measure of exposure, data is generally most relevant where monitoring sites are located in residential or densely populated areas. Maps generated by interpolating between monitoring sites are thus susceptible to the distribution and location of the sites, and the assumptions made in interpolation. Allowance also needs to be made for the detection limits, accuracy and comparability of the measurement methods. In particular, care needs to be taken when comparing data from different monitoring networks, due to the possibility of differences in sampling or measurement techniques. When used as a basis for assessing exposure, it is also important to recognise that actual exposures depend fundamentally upon indoor concentrations and time activity patterns of individuals. As with all exposure measures, relationships with health are also subject to considerable confounding, which should be strictly controlled for in epidemiological studies.

CHILDHOOD MORBIDITY DUE TO ACUTE RESPIRATORY ILLNESS	HEALTH IMPACT
INDICATOR PROFILE	
Hazard	Outdoor air pollution Indoor air pollution
Rationale and role	The incidence of acute respiratory illness in young children has shown a marked increase in recent decades, in almost all countries of the world. Many possible risk factors have been identified which might account for this trend; one of the most important is exposure to air pollution both in the home and outdoors. This indicator is intended to provide a measure of the health impact of these exposures to air pollution in children. As such, it can be used: • to monitor trends in acute respiratory illness in children, in order to help prioritise policy action; • to map the distribution of the disease, in order to identify areas in need of special action; • to help identify specific at-risk groups in order to target intervention; • to analyse relationships between air pollution (and other risk factors) and respiratory health; • to assess the effectiveness of intervention strategies (such as air pollution control, traffic management, awareness raising campaigns).
Alternative methods and definitions	This indicator can be defined as the incidence of morbidity due to acute respiratory illness in children under five years of age. Since acute respiratory illness tend to be more common in boys than girls, it can usefully be standardised by gender. Where the aim is to investigate relationships with potential causative factors, stratification on the basis of other variables (e.g. ethnicity) may also be appropriate. Variations on this indicator are possible, depending on the availability of morbidity data. In some countries, sales of respiratory medication (e.g. inhalers) can be used as a proxy, though this is non-specific to this age group; registrations at asthma clinics may also provide a proxy. The indicator could also be compiled and presented for other, more specific categories of acute respiratory infection, e.g.: • **Acute lower respiratory infection** (ALRI): an acute infection of the larynx, trachea, bronchi, bronchioles or lung. • **Acute upper respiratory infection** (AURI): an acute infection of the nose, pharynx (throat) or middle ear. Similar indicators might also be developed for other age groups considered to be at-risk (e.g. the elderly).
Related indicator sets	WHO *Catalogue of health indicators* Care-seeking for children with acute respiratory infections
Sources of further information	WHO 1992 *The measurement of overall and cause specific mortality in infants and children*. Report of joint WHO/UNICEF Consultation, 15-17 December 1992. WHO 1994 *Ninth general programme of work covering the period 1996-2001*. Geneva: WHO. WHO 1994 *The management of acute respiratory infections in children. Practical guidelines for outpatient care.* Geneva: for the Control of Diarrhoea and Acute Respiratory Diseases, WHO. WHO 1996 *Catalogue of health indicators: a selection of health indicators recommended by WHO programmes*. Geneva: WHO. WHO 1997 *Health and environment in sustainable development. Five years after the Earth Summit*. Geneva: WHO.

Involved agencies	WHO – Department of Child and Adolescent Health and Development (CAH) UNICEF
EXAMPLE INDICATOR	
Definition of indicator	Incidence of morbidity due to acute respiratory infections in children under five years of age
Underlying definitions and concepts	This indicator is based on the following definitions: • **Acute respiratory infection** *(ARI): an acute infection of the ear, nose, throat, epiglottis, larynx, trachea, bronchi, bronchioles or lung.* • **Total population of children under five years of age**: number of live children less than five years of age at the midpoint of the year (or other survey period).
Specification of data needed	Number of cases of acute respiratory infection (ARI) in children under five years of age. Total number of children under five years of age.
Data sources, availability and quality	Data on the number of cases of acute respiratory infection amongst young children may be obtainable from a number of different sources, including hospital admissions, GP records and special surveys. None of these sources is comprehensive and wholly free of bias, and GP data are difficult to acquire. For most purposes, therefore, the best available data are likely to come either from hospital admissions records or by specially designed surveys. The former includes only the more severe cases, and will omit cases which are not referred to hospital (e.g. which are treated at home or by the GP). Special surveys are inevitably based on relatively small samples, and may also suffer from bias or inconsistency in reporting. Data on the total number of children under five years of age are available from national census statistics, and should be reliable, especially for census years. Inter-censal estimates may be made using vital registration data or demographic models, but may contain some uncertainties due to effects of migration. These are likely to be significant only at the small area scale.
Computation	The indicator can be computed as: $1000 * (R_c / P_c)$ where R_c is the total number of cases of acute respiratory infection in children under five years of age in the survey period (e.g. the last calendar year), and P_c is the total number of children under five years of age at the mid-point of that survey period.
Units of measurement	Number per thousand children under five years of age.
Scale of application	Mainly local to regional; problems of data consistency limit application at broader scales.
Interpretation	This indicator is intended to provide a measure of changes or differences in the incidence of acute respiratory infections, as a result of exposure to air pollution. In this context, an increase in the morbidity rate may be taken to infer an increase in exposures; a reduction in morbidity may imply a decrease in levels or frequency of exposure. In practice, however, such interpretations are problematic. Exposure to air pollution is only one of many possible causes of acute respiratory infection; other risk factors include exposures to house dust mite, damp and mould in the home, food additives and pollen. Factors such as family history, sibling order and genetic predisposition are also important. Associations between the incidence of acute respiratory infection and air pollution are thus complex and highly confounded. Data on morbidity are also limited and often inconsistent, making comparisons between different countries or interpretations of trends potentially difficult. Many cases go unreported. Differences in the structure of the health service (e.g. the extent of provision of asthma clinics) and in diagnosis also affect the reported rates. Attempts to combine statistics from different sources pose difficulties because of differences in classification and possible double-counting of individual cases. As with all morbidity measures, therefore, this indicator needs to be interpreted with care.

CHILDHOOD MORTALITY DUE TO ACUTE RESPIRATORY ILLNESS	HEALTH IMPACT
INDICATOR PROFILE	
Hazard	Outdoor air pollution Indoor air pollution
Rationale and role	Acute respiratory illness is the single largest cause of mortality in children under 5 years of age. This indicator measures the health impact of acute respiratory mortality in the high risk group of under-five year olds. As an indicator for environmental health it provides an indication of potential health effects associated with the important issues of air pollution (especially indoor and vehicle pollution) and other environmental issues such as crowding and socio-economic status. Death due to acute respiratory illness is most commonly associated with infection or obstruction of the lower respiratory tract (i.e. the larynx, trachea, bronchi, bronchioles or lung). By providing a measurement of mortality in the sensitive group of under-five year olds, this indicator also provides an indirect indication of potential health effects in older age groups. As a measurement of cause-specific mortality, this indicator can serve several purposes: • to establish the relative public health importance of acute respiratory illness as a cause of death; • to monitor trends over time and provide an early warning of the need for intervention; • to map variations in acute respiratory illness, as a basis for identifying areas requiring special interventions; • to monitor the effectiveness of policies and other interventions aimed at reducing acute respiratory mortality; • to help investigate associations between air pollution or other risk factors and mortality due to acute respiratory illness. • to provide an indication of the potential for other diseases associated with the same environmental health issues. An important example in developing countries is diseases such as chronic respiratory disease in women who as a result of exposure to domestic indoor air pollution from coal and biomass burning.
Alternative methods and definitions	This indicator can be defined as the annual mortality rate due to acute respiratory illness in children under five years of age. Since acute respiratory infections tend to be more common in boys than girls, it can usefully be standardised by gender. Where the aim is to investigate relationships with potential causative factors, stratification on the basis of other variables (e.g. ethnicity) may also be appropriate. The indicator could also be compiled and presented for other, more specific categories of acute respiratory illness, e.g.: • **Acute lower respiratory infection** (ALRI): an acute infection of the larynx, trachea, bronchi, bronchioles or lung. • **Acute upper respiratory infection** (AURI): an acute infection of the nose, pharynx (throat) or middle ear. In this way, the indicator could be applied to monitor or investigate disease-specific mortality: In developing countries, this might focus on the problem of pneumonia associated with biomass/coal-burning and indoor air pollution. (Typically this will comprise a high proportion of deaths due to acute respiratory illness in these countries.) In developed countries the growing problem of asthma associated with vehicle air pollution may prompt use of asthma-specific indicators. Similar indicators might also be developed for other age groups considered to be at-risk (e.g. the elderly).

Related indicator sets	WHO *Catalogue of health indicators* • Under-five deaths due to acute respiratory infections
Sources of further information	WHO 1992 *The measurement of overall and cause specific mortality in infants and children*. Report of joint WHO/UNICEF Consultation, 15-17 December 1992. WHO 1994 *Ninth general programme of work covering the period 1996-2001*. Geneva: WHO. WHO 1994 *The management of acute respiratory infections in children. Practical guidelines for outpatient care.* Geneva: for the Control of Diarrhoea and Acute Respiratory Diseases, WHO. WHO 1996 *Catalogue of health indicators: a selection of health indicators recommended by WHO programmes.* Geneva: WHO. WHO 1997 *Health and environment in sustainable development. Five years after the Earth Summit*. Geneva: WHO.
Involved agencies	WHO – Department of Child and Adolescent Health and Development (CAH) UNICEF
EXAMPLE INDICATOR	
Definition of indicator	Annual mortality rate due to acute respiratory infections in children under five years of age
Underlying definitions and concepts	The indicator is based on the following definitions: • **Acute respiratory infection** (ARI): an acute infection of the ear, nose, throat, epiglottis, larynx, trachea, bronchi, bronchioles or lung. • **Total population of children under five years of age**: number of live children less than five years of age at the midpoint of the year (or other survey period).
Specification of data needed	Annual number of deaths of children under five years of age due to acute respiratory infections (ARI). Total number of children aged under five years at the mid-point in the survey year.
Data sources, availability and quality	Data on childhood deaths due to ARI, especially in developing countries, are rare. In some countries, data may be available from demographic surveillance systems or from household surveys and, in some cases, from vital registration or sample registration systems. In a number of countries, the demographic surveillance surveys have included a verbal autopsy module aimed at collecting information on the cause of death in children.
Computation	This indicator can be computed as: $1000 * (M_c / P_c)$ where M_c is the number of deaths due to ARI in children under five years of age, and P_c is the total number of children under five years of age.
Units of measurement	Number of deaths per thousand children below age five each year.
Scale of application	Local to international, though at broader scales problems of data consistency and differences in the causes of infection cause difficulties for interpretation.
Interpretation	This indicator may be interpreted to show trends or patterns in mortality due to ARI as a result of exposure to air pollution. An increase in mortality rates might imply higher exposures and worsening air pollution conditions; a reduction in mortality might imply a decrease in exposures and an improvement in air quality. For many reasons, however, such interpretations need to be made with care. Crucially, the association between ARI mortality and air pollution is not simple. Many other factors may cause ARI, including exposures to dust mite and other allergens in the home; factors such as family history of atopy and sibling order are also important. In developing countries, HIV and malaria are extremely important factors in either causing lower respiratory infection, or presenting as LRI. These may thus have a substantial effect on observed death rates. Mortality is also highly dependent upon the effectiveness of the health care system and availability of treatment; indeed, in many developed countries, mortality rates for acute respiratory illness have remained broadly stable over recent decades, despite a large increase in morbidity.

ACCESS TO SAFE AND RELIABLE SUPPLIES OF DRINKING WATER	RISK
INDICATOR PROFILE	
Hazard	Drinking water contamination
Rationale and role	Contaminated drinking water is a major cause of illness and mortality, as a result of exposures both to infectious agents (e.g. *E. coli*, cryptosperidium) and to chemical pollutants (e.g. lead, disinfection products). Inadequate access to water in the home is also a major source of economic disadvantage (by requiring large commitment of human resources to fetching and carrying water). This indicator provides a measure of risk, in terms of access to safe drinking water. It can be used: • to monitor the degree of access to safe drinking water, as a basis for prioritising policy; • to identify areas with poor access, where specific interventions are needed; • to indicate the potential health risks from use of poor quality drinking water, or inadequate water supplies; • to investigate relationships between access to safe water and health outcomes; • to monitor progress towards environmental health objectives in terms of access to safe water.
Alternative methods and definitions	For general application, this indicator can be expressed as the percentage of people with access to safe and reliable supplies of drinking water. Defining the terms inherent in this indicator (i.e. 'safe', 'reliable' and 'access'), however, poses significant difficulties. Safe water implies that the water meets accepted drinking water quality standards, and poses no significant risk to health (e.g. from water-borne diseases). The safety of drinking water thus needs to be determined on the basis either of water quality monitoring, or evidence of effective treatment. A reliable supply implies a supply which is continuous, or guaranteed at all times of need (though short-term disruptions may occur to supplies in any system because of technical difficulties). Adequate access implies that the supply is available either in the home or, at worst, in close proximity. Each of these concepts and definitions may need to be varied, depending on local circumstances and expectation: e.g. between rural and urban areas, or between more and less developed countries. In developed countries, for example, the expectation is likely to be of a supply direct to the home. In developing countries, it may be considered acceptable to collect water from a local source. In the latter case, the distance to the source must be defined. A distance of 1000 metres is proposed by the WHO/UNICEF Global water supply and sanitation assessment 2000. However, shorter distances may be more appropriate in many cases.
Related indicator sets	*UN* Indicators of sustainable development • Access to safe drinking water WHO *Catalogue of health indicators* • Access to safe drinking water UNCHS (Habitat) *Urban indicators programme* • Household connect levels • Access to potable water
Sources of further information	UN *1996 Indicators of sustainable development. Framework and methodologies*. New York: UN. WHO 1981 *Development of indicators for monitoring health for all by the year 2000*. p.29. Geneva: WHO. WHO 1982 *National and global monitoring of water supply and sanitation.* CWS series of Cooperative Action for the decade, No.2. WHO 1994 *Ninth general programme of work covering the period 1996-2001*. Geneva: WHO.

Sources of further information	WHO 1994 *Implementation of the Global Strategy for Health for All by the year 2000. Second evaluation. Eighth report on the world health situation*. Geneva: WHO Regional Office for Europe, Volume 5, European Region. WHO *1996 Catalogue of health indicators: a selection of health indicators recommended by WHO programmes*. Geneva: WHO. WHO/UNICEF 1996 *Water supply and sanitation sector monitoring report 1996*. WHO/UNICEF Joint Monitoring Programme. WHO/UNICEF 1999 *Global water supply and sanitation assessment 2000. Water supply and sanitation sector questionnaire, 1999*. (Draft report). UNCHS Urban Indicators Programme web page: http:/www.urbanobservatory.org/indicators/database/
Involved agencies	WHO-Programme for the Promotion Environmental Health UNICEF UN - Centre for Human Settlements (Habitat) Water Supply and Sanitation Collaborative Council National water companies and water authorities
EXAMPLE INDICATOR	
Definition of indicator	Percentage of the population with access to an adequate amount of safe drinking water in the dwelling or within a convenient distance from the dwelling.
Underlying definitions and concepts	The indicator is based on the following definitions: • **Access to safe water**: access to a safe and adequate supply of water either in the dwelling or within a convenient distance from the dwelling. • **Safe water**: water which either naturally, or as a result of treatment, is free from harmful or distasteful contaminants. • **Convenient distance**: May be defined as 15 minutes walking distance each way, or <1000 metres. This definition might vary from rural to urban areas. • **Adequate supply of water**: a continuous supply of water, sufficient to meet the needs of the user for drinking and hygiene. The minimum volume required may be defined as 20 litres per person per day. • **Continuous supply**: a supply which operates, without interruption, 24 hours per day. • **Total population**: total resident population.
Specification of data needed	Number of people with access to adequate supplies of safe drinking water. Total population.
Data sources, availability and quality	Data on the availability of, and access to, piped or public water supplies or water supplies provided under a formal licensing scheme (e.g. licensed abstractions from wells) may be obtained both from censuses and from relevant administrative authorities (e.g. water companies, public works departments). Data on access to informal supplies will usually need to be obtained via household surveys. Data on total population are available from national censuses and should be reliable.
Computation	The indicator can be computed as: $100 * (P_a / P_t)$ where P_a is the number of people with access to adequate and safe water supplies, and P_t is the total population.
Units of measurement	Percentage
Scale of application	Mainly local to national; application at broader scales is limited by problems of data availability and consistency.
Interpretation	This indicator provides a measure of the access to adequate and safe drinking water, and thus to potential health effects of dependence on inadequate or unsafe supplies. In general, an increase in the percentage of the population with access to safe drinking water may be taken as an indication of reduced exposure and health risk. Nevertheless, in interpreting the indicator, it is important to recognise that data on the quality, accessibility and adequacy of water supplies are often poor, especially in relation to non-piped water supplies.

CONNECTIONS TO PIPED WATER SUPPLY	RISK
INDICATOR PROFILE	
Hazard	Drinking water contamination
Rationale and role	Contaminated drinking water is a major cause of illness and mortality, as a result of exposures both to infectious agents (e.g. *E. coli*, cryptosperidium) and to chemical pollutants (e.g. lead, disinfection products). Inadequate access to water in the home is also a major source of economic disadvantage (by requiring large commitment of human resources to fetching and carrying water). Provision of piped water thus provides one of the main ways of improving, both the quality of, and access to, drinking water, and as such has major health benefits. This indicator gives a measure of the potential risk to health from drinking water. As such it can be used: • to identify areas with poor levels of connection to piped water supplies (and thus where health risks are potentially increased), as a basis for targetting action and resources; • to monitor progress towards targets to improve the water supply network; • to identify and quantify the number of people at risk from inadequate water supply; • to study relationships between water supply conditions and human health.
Alternative methods and definitions	This indicator could be expressed as the percentage of the population with (or alternatively without) access to piped water in the home. It could also be based on the number of households (rather than total population) if appropriate (e.g. when data on the number of people living in households connected to the water supply system are not available).
Related indicator sets	UNCHS (Habitat*) Urban indicators programme* • Household connection levels • Access to potable water
Sources of further information	WHO 1982 *National and global monitoring of water supply and sanitation*. CWS series of Cooperative Action for the decade, No.2. WHO 1994 *Implementation of the Global Strategy for Health for All by the year 2000. Second evaluation. Eighth report on the world health situation*. Geneva: WHO Regional Office for Europe, Volume 5, European Region. WHO/UNICEF 1996 *Water supply and sanitation sector monitoring report, 1996*. WHO/ UNICEF Joint Monitoring Programme. WHO/UNICEF 1999 *Global water supply and sanitation assessment 2000. Water supply and sanitation sector questionnaire, 1999*. (Draft report). UNCHS Urban Indicators Programme web page: http://www.urbanobservatory.org/ indicators/database/
Involved agencies	WHO-Programme for the Promotion Environmental Health UN - Centre for Human Settlements (Habitat) UNICEF Water Supply and Sanitation Collaborative Council National water companies and water authorities
EXAMPLE INDICATOR	
Definition of indicator	Percentage of the population receiving piped water to the home
Underlying definitions and concepts	This indicator is based on the assumption that access to piped water supplies can substantially reduce exposures to contaminated drinking water. Underlying definitions are: • **Piped water supply to the home:** existence of a permanent piped water system, providing treated water direct to the home • **Total population:** total resident population

Specification of data needed	Number of people living in households connected to the piped water supply Total population
Data sources, availability and quality	Data on number of people living in households receiving piped water to the home may be available from national water agencies or government statistics, and are liable to be broadly reliable. Alternatively, data may be obtained from household surveys. Data on the total population should be available through national census statistics and should be reliable
Computation	The indicator can be computed as: $(P_w / P_t) * 100$ where P_W is the number of people living in households receiving piped water to the home, and P_t is the total populations. The indicator should usually be calculated for a specified census date.
Units of measurement	Percentage
Scale of application	Local to international
Interpretation	This indicator provides a measure of the potential exposures to contaminated drinking water. In general, an increase in the proportion of households receiving piped water to the home may be taken as an indication of reduced exposure and health risk. Nevertheless, in interpreting the indicator, it is important to recognise that: • No allowance is made for differences in the quality of the supply; intermittent or poorly treated supplies may still pose significant health risks. Unreliable supplies, in particular, may encourage unsafe water storage in the home and exacerbate risks of water-borne disease. • For some forms of contamination (e.g. lead) old or poorly maintained water supply systems may be an important exposure source

OUTBREAKS OF WATER-BORNE DISEASES	HEALTH IMPACT
INDICATOR PROFILE	
Hazard	Surface water pollution Drinking water contamination
Rationale and role	Water-borne continue to be a major cause of ill health and death across much of the developing world. This indicator is intended to provide a measure of this human disease burden. It can be used: • to monitor changes in the number of reported outbreaks; • to help assess the effectiveness of intervention programmes (e.g. aimed at improving drinking water quality); • to identify areas with high rates of disease, where specific actions need to be taken; • to raise awareness about the problem, and encourage action at the local or national level.
Alternative methods and definitions	Various measures are available, on which to base an indicator of waterborne diseases. One of the most useful and widely used is the number of **outbreaks** of waterborne diseases in any survey period; this recognises the circumstance that most occurrences of waterborne disease occur as linked cases, relating to a single water source or pathway of exposure. Alternatively, indicators can be developed on the basis of the number of cases of waterborne disease. Although this gives a better measure of the total disease burden, it is less useful for management purposes, since intervention is usually aimed not at treating individual cases, but at preventing or controlling outbreaks at source. Either of these measures might also be applied to specific health endpoints; one example, is the set of indicators relating to dranunculiasis (Guinea-worm) developed by the WHO as Indicators for Monitoring the Health of the General Population (WHO 1996).
Related indicator sets	WHO *Catalogue of health indicators* • monthly incidence of Guinea-worm cases • annual incidence of Guinea-worm cases • villages with new cases of Guinea-worm
Sources of further information	WHO 1992 *Our planet, our health*. Geneva: WHO. WHO 1996 *Catalogue of health indicators*. Geneva: WHO. WHO Collaborating Center for Research, Training and Control of Dracunculiasis (no date) *Guidelines for surveillance in Dracunculiasis eradication programs*. Atlanta, USA: CDC.
Involved agencies	WHO-Afro
EXAMPLE INDICATOR	
Definition of indicator	Incidence of outbreaks of water-borne diseases

Underlying definitions and concepts	• **Water-borne disease:** a disease which arises from the contamination of water by human or animal faeces or urine infected by pathogenic viruses or bacteria, and which is directly transmitted when the water is drunk or used in the preparation of food. Water-borne diseases may be separated from several other categories of disease, including:
	  • water-washed diseases - i.e. those resulting from inadequate personal hygiene because of scarcity or inaccessibility of water (e.g many waterborne diseases as well as typhus)
	  • water-based diseases - those arising from parasites which use an intermediate host that lives in or near water (e.g. dracunculiasis)
	  • water-related diseases - diseases borne by insect vectors which have habitats in or near water (e.g. malaria), and

Underlying definitions and concepts (continued)	• water-dispersed diseases - infections whose agents proliferate in fresh water and • 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. **Total population:** total resident population during the survey period.
data needed	Number of outbreaks of water-borne diseases within a specified area within a specified Total population
Data sources, availability and quality	of sources, including: routine passive case reporting by health care workers • • special surveys analysis of hospital admission or GP statistics and records All of these are likely to lead to significant under-estimation of the number of outbreaks, also occur between different areas or reporting periods because of variations in referral rates, in diagnosis and in reporting methods and accuracy. should be reliable.
Computation	1000* (N / P) where N is the number of reported outbreaks and P is the total population.
Scale of application	Number of outbreaks per thousand head of population data consistency and completeness.
Interpretation	incidence of outbreaks of waterborne diseases. Considerable care is needed, however, because of the inherent inconsistencies and inaccuracies in the available to infer the absolute numbers of cases, since outbreaks may vary greatly in terms of the numbers of people affected.

DIARRHOEA MORBIDITY IN CHILDREN	HEALTH IMPACT
Hazard	Drinking water contamination
Rationale and role	five-year olds. It is an indication of the magnitude of the problem of diarrhoea and the potential health effects from exposure to the environmental problems of poor quality As a measurement of cause-specific morbidity this indicator can serve several purposes: • public health importance; • impact of intervention, management and control programmes; • • to select, target and programme interventions; to monitor the effectiveness of intervention programmes.
Alternative methods and definitions	age. Where appropriate it could be applied to other age groups (e.g. 0-1 year old). admissions for acute gastro-intestinal infections. This, however, would tend to underestimate the incidence of illness because only the most serious cases would be in access to hospital.
Related indicator sets	*Catalogue of health indicators* •
Sources of further information	WHO 1992 . Division for the Control of WHO 1994 *Ninth general programme of work covering the period 1996-2001* WHO. WHO 1994 . WHO/CDR/94.8. Geneva: WHO. *Catalogue of health indicators: A selection of health indicators recommended by WHO Programmes.* WHO 1997 *Health and environment in sustainable development – five years after the* . Geneva: WHO.
Involved agencies	WHO – Programme for Promotion of Environmental Health UNICEF
Definition of indicator	Incidence of diarrhoea morbidity in children under five years of age.
	Diarrhoea: three or more watery stools in a 24-hour period, a loose stool being one that would take the shape of the container (WHO 1996), or local definition of diarrhoea. **Episode of Diarrhoea:** or more loose or watery stools. An episode of diarrhoea is considered to have ended after 48 hours without three or more loose watery stools within a 24-hour period. total number of episodes of diarrhoea during a 1-year period amongst the children surveyed. number of children less than five years of age in the survey, at the time of survey.

Specification of data needed	Data on number of episodes of diarrhoea among children under five. Population data for total number of children under five years of age. Disaggregating data such as socio-economic status, geographic area and age/sex of children.
Data sources, availability and quality	Morbidity data for diarrhoea disease does not tend to be collected on a routine basis, and usually depends on special surveys. Methods for data collection by surveys are recommended by the WHO Division for the Control of Diarrhoea and Acute Respiratory Disease (CDD/ARI) household survey manual (see Sources of further information). The CDD/ARI Household Survey is designed to collect qualitative as well as quantitative information on diarrhoea episodes occurring in the past two weeks. The manual includes instructions on how to convert the results to an annual incidence taking into account seasonal variations.
Computation	The indicator can be computed as: I_c / P_c where I_c is the incidence of diarrhoea in children under five years of age in the survey, and P_c is the total number of children under five years of age in the survey.
Units of measurement	Number of cases per child per year.
Scale of application	Local to national; application at broader scales is limited by problems of data consistency and completeness.
Interpretation	This indicator is a powerful measure of health status of children, especially under conditions of inadequate water or food hygiene and basic sanitation. Action to improve these conditions can generally help to reduce morbidity rates. Like other infectious diseases, however, marked short-term variations in morbidity may occur, making identification of long-term trends difficult, especially on the basis of short-term or irregular surveys. Data on the incidence of diarrhoea are also subject to large margins of error due to inconsistencies in reporting and in definitions, and problems of ensuring adequate sampling in surveys. Interpretation of the indicator can be assisted by disaggregating the data by age and gender of the child, economic status of the parents and geographic area.

DIARRHOEA MORTALITY IN CHILDREN	HEALTH IMPACT
INDICATOR PROFILE	
Hazard	Surface water pollution Drinking water contamination
Rationale and role	Diarrhoea and related gastrointestinal illnesses continue to be one of the most important causes of illness and death, worldwide especially amongst vulnerable groups such as young children. Much of this illness is due to exposures to contaminated water or food, as a result, for example, of poor water quality, limited access to water, poor food hygiene and safety, or poor sanitation in the home. Major pathogens include Salmonella, Shigella, *Campylobacter*, *E. coli* and rotavirus. This indicator provides a measure of the extent and severity of these effects. It can thus be used: • to monitor general trends in the burden of disease amongst children; • to infer changes in the quality of drinking and bathing water, food and basic sanitation; • to map patterns of disease, as a basis for identifying at-risk areas or groups, and target policy action; • to assess and monitor the effectiveness of intervention programmes; • to analyse relationships between environmental exposures and health.
Alternative methods and definitions	This indicator can be defined as the mortality rate due to diarrhoea in children under five years of age. It could alternatively be assessed using a broader category of illnesses (e.g. diseases of the digestive system - ICD codes 520-579). While this would broaden the potential range of exposures of relevance, it would tend to reduce inconsistencies due to diagnosis. It could also be applied to other age groups (e.g. < 1 year) where appropriate. Stratification by gender may be useful in some cases.
Related indicator sets	WHO *Catalogue of health indicators* • Deaths due to diarrhoea among infants and children under 5 years of age
Sources of further information	WHO 1992 *Readings on diarrhoea: student manual*. Division for the Control of Diarrhoea and Acute Respiratory Disease, Geneva: WHO. WHO 1994 *Ninth general programme of work covering the period 1996-2001*. Geneva: WHO. WHO 1994 *Household survey manual: diarrhoea and acute respiratory infections*. WHO/CDR/94.8. Geneva: WHO. WHO 1996 *Catalogue of health indicators: a selection of health indicators recommended by WHO Programmes*. Geneva: WHO. WHO 1997 *Health and environment in sustainable development – five years after the Earth Summit*. Geneva: WHO.
Involved agencies	WHO – Department of Child and Adolescent Health and Development (CAH) WHO – Programme for Promotion of Environmental Health UNICEF
EXAMPLE INDICATOR	
Definition of indicator	Diarrhoea mortality rate in children under five years of age
Underlying definitions and concepts	**Death due to diarrhoea in children under five years of age**: death in which diarrhoea is defined as a primary cause of a child of less than five years of age at the time of death. **Total population of children under five years of age**: number of live children less than five years of age at the midpoint of the survey year (or other survey period).
Specification of data needed	Total number of deaths due to diarrhoea in children under five years of age. Total population of children under five years of age.

Data sources, availability and quality	Data on death due to diarrhoea in children under five years of age should be available through national or regional/local death statistics. Differences in both diagnosis and reporting practice may be significant in these data, especially where diarrhoea is part of a complex of symptoms (e.g. associated with malnutrition). Where statistical data are not available from routine sources, special surveys will be necessary. Data on the total population of children under five years of age should usually be available via national censuses. Inter-census estimates can be made using vital registration data, or demographic models. Care is needed in applying a consistent and appropriate census date, especially where marked seasonal patterns in birth may occur.
Computation	The indicator can be computed as: $1000 * (M_c / P_c)$ where M_c is the total number of deaths amongst children under five years of age and P_c is the total population of children under five years of age.
Units of measurement	Number per thousand children under five years of age.
Scale of application	Local to international, though at broader scales extreme care is needed in interpretation because of problems of data consistency and completeness.
Interpretation	This indicator is a powerful measure of health status of children, especially under conditions of inadequate water or food hygiene and basic sanitation. Action to improve these conditions can generally help to reduce mortality rates. Like other infectious diseases, however, marked short-term variations in mortality may occur, making identification of long-term trends difficult. Death of young children due to diarrhoea may also be a result of several different, and often inter-related, exposures: attributing changes in mortality to any one of these without consideration of the others might be misleading. Rates of mortality are also fundamentally affected by the effectiveness of, and access to, the health service and levels of awareness amongst parents.

FOOD-BORNE ILLNESS	HEALTH IMPACT
INDICATOR PROFILE	
Issue	Biological contamination of food
Rationale and role	Poor food hygiene is a major source of infection and ill health, worldwide. Problems may occur throughout the food chain, from primary food production, through processing, manufacturing and sale, to preparation and use in the home. This indicator provides a measure of the health impact of exposures to food-borne pathogens. It can be used: • to determine the magnitude of the public health problem posed by food-borne diseases; • to monitor trends in the incidence of food-borne diseases, as a basis for prioritising and planning action; • to help raise awareness about the issues of food hygiene amongst food producers, health officials and the public; • as part of epidemiological studies, to help investigate relationships between specific risk factors or exposures and human health; • to monitor and assess the effectiveness of programmes to improve food safety.
Alternative methods and definitions	The rate of food-borne illness in the population can be determined in two main ways: in terms of the number of cases (often referred to as the incidence rate) or in terms of the number of outbreaks (the outbreak rate). For policy purposes, the latter is often most useful, since events often occur as outbreaks, associated with a common food source. Much of the policy and management effort is thus aimed at preventing or controlling outbreaks. Given this, one of the most useful ways of defining this indicator is as the number of outbreaks of food-borne illness per thousand head of population, within a given time period. A relatively small proportion of cases arise as part of detectable outbreaks, however, so the indicator tends to under-estimate the magnitude of total public health problem. Where data permit, this indicator can usefully be disaggregated to provide information on the outbreak rates for different categories of food-borne illness. Disaggregation by age, gender, socio-economic character and geographic area is also likely to be informative in many cases. As an alternative, an indicator might also be devised to provide information on the incidence rate of food-borne illness – i.e. the number of individual cases per thousand heads of population. This provides a better measure of the overall public health problem, but is less useful as a guide to intervention.
Related indicator sets	WHO *Catalogue of health indicators* • Annual incidence of diarrhoea in children under 5 years of age • Deaths due to diarrhoea among infants and children under 5 years of age
Sources of further information	WHO 1996 *Catalogue of health indicators: a selection of health indicators recommended by WHO Programmes*. Geneva: WHO. WHO 1997 *Health and environment in sustainable development. Five years after the Earth Summit.* Geneva: WHO. WHO 1997 *Surveillance of food-borne diseases: what are the options?* WHO/FSF/FOS/97.3. Geneva: WHO Food Safety Unit. WHO 1997 *Prevention and control of Enterohaemorrhagic Escherichia coli (EHIC) infections*. Report of a WHO Consultation, Geneva, Switzerland, 28 April-1 May 1997. WHO/FSF/FOS/97.6. Geneva: WHO Food Safety Unit. WHO *Guidelines for investigation and control of food-borne disease outbreaks*. Geneva: WHO. In preparation.

Involved agencies	WHO - Food Safety Unit FAO National food protection agencies. National ministries of agriculture.
EXAMPLE INDICATOR	
Definition of indicator	Outbreak rate of food-borne illness
Underlying definitions and concepts	The indicator is based on the following definitions: • **Food:** any substance, whether processed, semi-processed or raw which is intended for human consumption, including drinks, chewing gum and any substance which has been used in the manufacture, preparation or treatment of 'food' but excluding cosmetics, tobacco and substances used only as drugs. • **Food-borne illness:** medically certified condition(s) (i.e. presence of pathogen/ toxin and adequate clinical symptoms) arising from the ingestion of food or water. • **Outbreak**: two or more linked cases of the same illness. • **Total population**: total resident population.
Specification of data needed	Number of outbreaks or number of cases, per year (or other specified survey period). Total population.
Data sources, availability and quality	Outbreaks of food-borne diseases may be reported by a wide range of individuals and agencies, including the public, the media, health care providers and practitioners, and laboratories dealing with samples referred for analysis. In many countries, statutory notification systems also exist for some types of food-borne disease. Data on outbreaks are often collated by public health authorities. In all cases, however, the quality and the completeness of the data may be variable, because of incomplete reporting (many cases may not be referred to health services) and inconsistencies in diagnosis. Post hoc investigations of outbreaks may also be undertaken, though these are likely to cover only more severe or unusual outbreaks. Data on total population are available from national censuses and should be reliable.
Computation	The indicator can be computed as: $1000 * (O_f / P_t)$ where O_f is the number of outbreaks of food-borne illness f in the survey period, and P_t is the total population.
Units of measurement	Number of outbreaks per thousand head of population.
Scale of application	Local to international, though problems of data consistency and completeness may limit applications at broader scales.
Interpretation	This indicator provides a measure of the health burden associated with exposure to food-borne pathogens. In general terms, therefore, an increase in the rate of outbreaks may be interpreted as evidence of a deterioration in health conditions and an indication of increased problems of food hygiene; a reduction in the rate of outbreaks of illness may be taken as an implication of an improvement in health conditions and in food hygiene. Problems of data quality and availability, however, need to be taken into account. Different methods of monitoring and reporting are liable to give very different results, and care is needed in comparing or pooling data from different sources. Substantial uncertainties in the data also arise due to variations in diagnosis, reporting methods, health system infrastructure and the perceptions of the public. The episodic nature of food-borne disease outbreaks also means that long-term trends should not be inferred from short runs of data; the clustered nature of outbreaks similarly means that national patterns should not be deduced from local surveys. It also needs to be borne in mind that only a small proportion of the total number of cases of food-borne illness occur in the form of outbreaks. As specified here, therefore, this indicator cannot be used directly to infer the incidence rate (or the magnitude of the total public health problem) of food-borne illness.

POPULATION AT RISK FROM VECTOR-BORNE DISEASES	RISK
INDICATOR PROFILE	
Hazard	Water-borne disease vectors Animal-borne disease vectors
Rationale and role	Vector-borne diseases are a major cause of both morbidity and mortality, especially in the developing world. This indicator is intended to evaluate the number of people at-risk from vector-borne diseases, by virtue of living in areas infected with the disease vectors. It can thus be used: • to assess the numbers of people at risk; • to identify areas of particular risk, where special action is required; • to assess and compare the effectiveness of control programmes (e.g. habitat removal or management, pest control measures).
Alternative methods and definitions	The accurate determination of the number of people at risk from vector-borne diseases is, in practice, complex. For a real risk to occur, three preconditions need to exist: a parasite, a suitable vector and a susceptible host population. These also need to come into contact (and to do so at relevant points in the lifecycle of the parasite). Rarely are detailed data available on these factors at an appropriate spatial and temporal scale. A simple indicator can, however, be constructed in terms of the number of people living in areas endemic for vector-borne diseases. This provides a general indication of the *potential* for exposure. Where appropriate, this indicator should be separately defined for each disease and/or vector species. Where reliable data on population are not available, this indicator might alternatively be defined in terms of the endemic area. This, however, will clearly make no distinction between densely and sparsely populated regions. Another alternative for this indicator is the Entomological Inoculation Rate (EIR). This is widely used in relation to malaria, for example, to indicate the transmission intensity.
Related indicator sets	WHO *Catalogue of health indicators* • Incidence rate of severe malaria
Sources of further information	WHO 1994 *Information systems for the evaluation of malaria control programmes, a practical guide*. AFRO/CTD/MAL/ 94.3. Brazzaville: WHO Regional Office for Africa. WHO 1996 *Catalogue of health indicators: a selection of health indicators recommended by WHO Programmes*. Geneva: WHO.
Involved agencies	UNDP UNICEF WHO-Afro – Malaria Unit World Bank
EXAMPLE INDICATOR	
Definition of indicator	Number of people living in areas endemic for vector-borne diseases
Underlying definitions	• **Vector-borne disease:** a disease which is transmitted by a biological agent (often an insect). Common vector-borne diseases include malaria, yellow fever, dengue fever, river blindness (onchocerciasis), filiariasis, schistosomiasis, Japanese encephalitis and sleeping sickness. Many of the most important vector-borne diseases are water-related, in that the insect vectors concerned breed or pass part of their lifecycle in or close to water. Vector-borne diseases have thus been exacerbated in many cases by inappropriate water-engineering (e.g. irrigation) or poor management of water resources and wastes (e.g. poor sanitation). Some vector-borne diseases are also animal-related (e.g. bubonic plague, sleeping sickness), in that the insect vectors are associated with specific animal hosts. In these cases, land use and land cover are important factors in their distribution and prevalence. • **At-risk population:** the population at risk from vector-borne disease, by virtue of living in, or visiting, an endemic area**.**
Specification of data needed	At-risk population

Data sources, availability and quality	Reliable data on the at-risk population are difficult to obtain, but estimates can be made by analysis of national census data and information on the extent of the vector-borne diseases of interest. GIS techniques might usefully be applied in order to estimate the number of people living in the endemic area (e.g. by overlaying boundaries of the infected area on population data). Where data on the extent of the endemic area are not directly available, estimates may be made on the basis of the distribution of potential vector habitats (e.g. using remotely sensed data). In this case, the endemic area may be defined by buffering around each potential habitat at an appropriate distance (depending on the parasite and vector concerned).
Computation	The indicator can be computed as the number of people living within endemic areas, or living within a specified distance of potential vector habitats. Separate estimates should be made for each type of vector-borne disease and vector species.
Units of measurement	Number of people.
Scale of application	Local to international, though at broader scales interpretation is limited by problems of data consistency and completeness.
Interpretation	This indicator provides a general measure of the population at risk from vector-borne diseases: an increase in the numbers of people living in endemic areas may be taken to imply an increased risk, a reduction the reverse. Nevertheless, in interpreting the indicator it is important to take account both of the potential uncertainties in the data, and the possible complexities in the relationship between place of residence and risk. Data on the extent of the endemic area, for example, may be unreliable both because of omission (i.e. exclusion of unknown endemic areas) and commission (inclusion of non-endemic areas). These errors are likely to increase as the scale of mapping becomes smaller (i.e. less detailed). The actual risk across the population living within an endemic area is also likely to vary substantially, depending on local conditions (below the resolution of the available data), age, disposable income and lifestyle. There are, for example, important micro-epidemiological differences in malaria, so that even at the community level the disease may be clustered in certain families. It is also important to remember that people are not static, but move both within and through the area. Thus the at-risk population may change over time, and includes visitors to, or past residents of, the endemic area.

MORTALITY DUE TO VECTOR-BORNE DISEASES	HEALTH IMPACT
INDICATOR PROFILE	
Hazard	Water-borne disease vectors Animal-borne disease vectors
Rationale and role	Vector-borne diseases are a major cause of both morbidity and mortality, especially in the developing world. This indicator is devised to provide a measure of the effect of exposure to disease vectors. It can be used to: • monitor changes in mortality rates due to vector-borne diseases, in order to identify trends and plan control strategies; • assess the effectiveness of vector-control or health care strategies; • identify areas with especially high rates of mortality, which may need special interventions; • analyse relationships between environmental conditions likely to affect exposures (e.g. land use, climate change) and health outcome.
Alternative methods and definitions	Where appropriate data are available, the most appropriate way of defining this indicator is in terms of the mortality rate due to vector-borne diseases, by type of disease. Since children are often the most vulnerable to vector-borne diseases, this indicator could usefully be stratified by age (including 0-4 year old and 5-15 year old age groups). Pregnant women are also an important susceptible group, so the indicator might also be separately computed for these. The indicator can be simplified by presenting only the aggregate death rate for all vector-borne diseases. This, however, may mask important environmental and policy-related differences (e.g. by masking changes in diseases associated with specific vectors, habitats or land use systems).
Related indicator sets	WHO *Catalogue of health indicators* • Incidence rate of severe malaria
Sources of further information	WHO 1994 *Information systems for the evaluation of malaria control programmes, a practical guide*. AFRO/CTD/MAL/ 94.3. Brazzaville: WHO Regional Office for Africa. WHO 1996 *Catalogue of health indicators: a selection of health indicators recommended by WHO Programmes*. Geneva: WHO.
Involved agencies	UNDP UNICEF WHO-Afro – Malaria Unit World Bank
EXAMPLE INDICATOR	
Definition of indicator	Mortality rate due to vector-borne diseases, by type
Underlying definitions and concepts	• **Vector-borne disease:** a disease which is transmitted by a biological agent (often an insect). Common vector-borne diseases include malaria, yellow fever, dengue fever, river blindness (onchocerciasis), filiariasis, schistosomiasis, Japanese encephalitis and sleeping sickness. Many of the most important vector-borne diseases are water-related, in that the insect vectors concerned breed or pass part of their lifecycle in or close to water. Vector-borne diseases have thus been exacerbated in many cases by inappropriate water-engineering (e.g. irrigation) or poor management of water resources and wastes (e.g. poor sanitation). Some vector-borne diseases are also animal-related (e.g. Lyme's disease), in that the insect vectors are associated with specific animal hosts. In these cases, land use and land cover are important factors in their distribution and prevalence. • **Total population:** total resident population.
Specification of data needed	Number of deaths due to vector-borne diseases Total population

Data sources, availability and quality	Data on the number of deaths due to vector-borne diseases can generally be obtained from routine health service sources, either nationally or locally. For some forms of vector-borne disease, mortality statistics are also collated as part of national or international surveillance programmes. Where routine data do not exist, special surveys may be necessary. In all cases, data may be subject to some uncertainties, due to incomplete or inconsistent reporting as a result both of the complex disease syndromes and limitations in the reporting services. Data on total population are usually available through national censuses, and should be reliable.
Computation	The indicator can be computed as: $1000 * (V_d / P)$ where V_d is the number of deaths due to vector-borne disease d within the survey period, and P is the total population.
Units of measurement	Number of deaths per thousand head of population
Scale of application	Local to international, though at broader scales interpretation is limited by problems of data consistency and completeness.
Interpretation	In general terms, this indicator provides a direct measure of the health effects of vector-borne diseases: an increase in the mortality rate may be interpreted as evidence of an increase in the health impacts, a reduction the reverse. As a mortality indicator, however, it provides information only on the most severe effects of these diseases; it does not show the much larger burden of morbidity which exists. Mortality rates are also highly dependent on the quality of the health care service, and on factors such as remoteness and access to health care. Differences in mortality rate need to be interpreted in this context. Some problems of data consistency and accuracy may occur, especially in remote or less developed areas where routine reporting is limited. Many vector-borne diseases also show natural periodicity (related, for example, to seasonal or inter-annual fluctuations in the vector population). Short-term trends therefore need to be interpreted with caution, and care is needed in inferring effects of intervention strategies over short periods.

SOURCES OF INDOOR AIR POLLUTION	RISK
INDICATOR PROFILE	
Hazard	Indoor air pollution
Rationale and role	Indoor exposures to air pollution are an important factor in respiratory illness and mortality. Much of this exposure relates to the use of fuels such as wood, kerosene, coal or dung for cooking and heating. The indicator thus provides a measure of the potential risk from exposure to air pollution from indoor sources. It can be used: • to show time trends in levels of potential exposure • to provide an early indication of the effects of changes in domestic energy supplies on indoor exposures to air pollution • to show geographic variations in levels of potential exposure • to compare areas or countries in terms of potential exposures • to monitor the effects of intervention strategies aimed at reducing sources of indoor exposures due to cooking and heating fuels
Alternative methods and definitions	This indicator can be computed as the number or proportion of households (or population) which rely on fuels such as coal, wood, dung and kerosene (or other high emission and poorly ventilated systems) for heating and cooking. Relevant data are often available from household surveys. Alternatively, the indicator could be defined as the percentage of households connected to electricity and gas supplies. Data on this may be available from censuses or from the utility companies. Another possible alternative would be to base the indicator on the percentage of total energy consumption provided by electricity or gas.
Related indicator sets	None
Sources of further information	WHO 1994 *Implementation of the Global Strategy for Health for All by the year 2000*. Second evaluation. Eighth report on the world health situation. Geneva: WHO Regional Office for Europe, Volume 5, European Region. WHO 1998 Healthy Cities Air Management Information System, AMIS 2.0. CDRom. Geneva: WHO.
Involved agencies	National energy supply companies National ministries of energy WHO-Afro
EXAMPLE INDICATOR	
Definition of indicator	Proportion of households using coal, wood, dung or kerosene as the main source of heating and cooking fuel
Underlying definitions and concepts	This indicator is based on the assumption that use of kerosene, wood, coal or dung for heating and cooking tends to increase levels of exposure to indoor air pollution. Underlying definitions are: • **Household:** a single dwelling unit (e.g. a house or apartment) intended for permanent residence. • **Use of coal, wood, dung or kerosene as the main source of heating and cooking fuel:** the reliance on coal (or lignite), wood, dung or kerosene as the primary cooking a and heating fuel in the home.
Specification of data needed	Number of households using coal, wood, dung or kerosene as the main source of heating and cooking fuel Total number of households

Data sources, availability and quality	Data on number of households using coal, wood, dung or kerosene as the main source of cooking and heating fuel may be available from census statistics or household surveys, and in these cases are liable to be broadly reliable. In many cases, however, data will need to be collected as part of special surveys. Data on the total number of households should be available through national census statistics, though care is needed in relation to the definition of a 'household' (e.g. how collective dwellings are classified).
Computation	The indicator can be computed as: (C / H) * 100 where C is the number of households using coal, wood, dung or kerosene as the main source of cooking/heating fuel; H is the total number of households. The indicator should normally be calculated for a specified census date.
Units of measurement	Percentage
Scale of application	Mainly local to regional; problems of data consistency limit its application at broader scales.
Interpretation	This indicator provides a general measure of differences or trends in exposure to air pollutants from indoor heating and cooking sources: a reduction in the percentage of homes relying on coal, wood, dung or kerosene may be taken to imply a reduced level of exposure. In applying and interpreting the indicator, however, it should be noted that: • it takes no account of use of other sources of indoor pollution (e.g. smoking, furnishings, solvents) • the indicator takes no account of the many other factors (e.g. lifestyle and ventilation behaviour) likely to affect exposures • relationships with health outcome may be heavily confounded by other factors, including exposures to outdoor and occupational pollution, housing conditions and socio-economic factors.

POPULATION LIVING IN UNSAFE HOUSING		RISK
INDICATOR PROFILE		
Hazard	Domestic accidents	
Rationale and role	The adequacy of housing is an important determinant of health status, in a number of ways. *Inter alia*, housing quality affects levels of exposure to indoor pollutants, food and water hygiene, levels of sanitation, exposures to physical hazards and injury, and general quality of life. Housing may be unsafe, therefore, for a variety of reasons, including: dangerous construction, inadequate ventilation, inadequate heating, dangerous or inadequately maintained services, inadequate size for the number of residents (i.e. overcrowding) or location in a hazardous area (e.g. areas prone to flooding or earthquakes, or on contaminated land). Living in inadequate housing is therefore likely to result in increased risks of a variety of health effects, including respiratory illness, gastro-intestinal infections and infant mortality. This indicator provides a general measure of the adequacy of the housing stock, and the level of exposures to these hazards which might thus occur. Potential uses include: • monitoring the general adequacy of the housing stock, and access to this stock by the population; • monitoring the magnitude and implications of major demographic or social changes in the population (e.g. as a result of rapid urbanisation or migration); • assessment of changes in the general level of health risk associated with poor housing; • mapping risks associated with poor housing, in order to identify areas of special need; • assessing the effectiveness of national or regional strategies aimed at improving the housing stock; • analysing relationships between quality of housing and health effects.	
Alternative methods	Although potentially valuable, this indicator is difficult to define and measure in a clear and systematic manner. The most appropriate measure would be the percentage (or number) of people living in unsafe, unhealthy or hazardous housing. Defining the terms ‘unsafe’, ‘unhealthy’ and ‘hazardous’, however, poses severe difficulties, as does obtaining data on houses which meet these criteria. A somewhat weaker alternative to this indicator can be obtained by assessing the percentage of the total housing stock which is considered unsafe, unhealthy or hazardous. Information can be obtained from housing condition surveys. This is liable to underestimate the number of people affected because of the tendency for overcrowding in poorer quality housing. A further alternative is to use census derived-data (e.g. on overcrowding or the availability of basic amenities in the home), where these exist, as a measure of inadequate housing. These terms are usually defined nationally by the census. Where the main concern is about natural hazards, such as flooding, earthquakes, avalanches or radon exposures, estimates of the exposed population may be made using GIS techniques to map hazardous areas and overlay these with population data.	
Related indicator sets	UNCHS (Habitat) *Urban Indicators Programme*: • Permanent structures (percentage of housing units located in structures expected to be maintain their stability for 20 years or longer under local conditions with normal maintenance) • Housing in compliance (percentage of the total housing stock in compliance with current regulations) • Housing destroyed (percentage of the housing stock destroyed by natural or man-made disasters over the past ten years)	

Sources of further information	WHO 1994 *Implementation of the Global Strategy for Health for All by the year 2000. Second evaluation. Eighth report on the world health situation.* Geneva: WHO Regional Office for Europe, Volume 5, European Region. WHO 1997 *Health and environment in sustainable development. Five years after the Earth Summit.* Geneva: WHO. UNCHS Urban Indicators Programme web page: http://www.urbanobservatory.org/indicators/database/
Involved agencies	UN - Centre for Human Settlements (Habitat) WHO Healthy Cities Programme National, regional and local housing agencies
EXAMPLE INDICATOR	
Definition of indicator	Percentage of the population living in unsafe, unhealthy or hazardous housing.
Underlying definitions and concepts	This indicator requires the ability to identify, and measure the extent of, unsafe, unhealthy or hazardous housing. This poses significant difficulties, for these are all to a large extent both environmentally and culturally dependent, and thus are liable to vary from one area (or one time) to another. Possible definitions of unsafe, unhealthy or hazardous housing include housing which is: • physically unsound and likely to be dangerous to its occupants, because of its poor construction, or inadequately maintained services (e.g. electricity); or • is located in a physically hazardous area (e.g. an area of flood or earthquake risk) or is sited on contaminated land (e.g. by chemical wastes, radioactivity); or • provides serious risks of exposures to indoor pollution (e.g. air pollutants) or pathogens (e.g. moulds, ticks, fleas); or • provides inadequate shelter (e.g. due to poor insulation, inadequate roofing) and basic amenities (e.g. cooking facilities, heating). In addition, a definition is required of the total population: i.e. the total resident population at the time of census or survey.
Specification of data needed	Number of people living in unsafe, unhealthy or hazardous housing Total resident population
Data sources, availability and quality	Data on the quality of the housing stock, and the number of people living in unsafe, unhealthy or hazardous housing is rarely available from routine sources. In some countries, an approximation to this may be available from census statistics (e.g. housing lacking basic amenities). Generally, however, data will need to be obtained by special surveys. In all cases, these data are liable to considerable margins of error and inconsistency due to difficulties of definition, inconsistent reporting and difficulties of ensuring representative sampling. Data on the total resident population should be available from national censuses and should be reliable.
Computation	The indicator can be computed as: $100 * (U / P)$ where U is the number of people living in unsafe, unhealthy or hazardous housing and P is the total population.
Units of measurement	Percentage
Scale of application	Mainly local

Interpretation	This is an important indicator, which has wide-ranging significance for policy. In providing a measure of the adequacy of the housing stock, it also acts as an indicator of health risks associated with poor sanitation, exposures to indoor air pollution, and access to safe water. It can therefore help to interpret a range of other issues and indicators. Like all general-purpose indicators, however, it needs to be interpreted carefully. The characteristics which render housing unsafe, unhealthy or hazardous may clearly vary; without information on these specific characteristics it can be misleading to infer either the existence of particular health risks or effects or the need for specific actions. Definitional issues are also likely to pose major difficulties for comparisons between different areas, or between different surveys, unless standard protocols have been used. A clear understanding of the data is therefore essential before interpretations are made.

ACCEPTED	
ACCIDENTS IN THE HOME	**HEALTH IMPACT**
INDICATOR PROFILE	
Hazard	Domestic accidents
Rationale and role	Accidents in the home are one of the main causes of injury and death. Though accidents can occur in any home, the risk of accidents tends to be increased by poor building design and inadequate safety requirements for housing. This indicator thus provides a measure of the health impact of inadequate housing. It can be used: • to monitor the incidence of accidents in the home; • to identify areas or types of housing with unacceptably high rates of accident or injury, as a basis for targeting action; • to help develop and design safer houses; • to help establish more effective planning and building regulations; • to assess the effectiveness of policy interventions, aimed at reducing accidents in the home - e.g. new building regulations or awareness raising campaigns.
Alternative methods and definitions	This indicator can be defined as the incidence of injury by accidents in the home. Because the young and elderly are the most vulnerable to accidents in the home, it may be appropriate to stratify the indicator by age (and perhaps gender) or to restrict it to specific age groups.
Related indicator sets	None
Sources of further information	
Involved agencies	WHO
EXAMPLE INDICATOR	
Definition of indicator	Incidence of injury by accidents in the home
Underlying definitions and concepts	**Accidents in the home**: an accident, taking place in the home, which leads to physical injury sufficient to require medical treatment. Common accidents include falling down stairs, electrocution, burning, scalding and accidents with kitchen utensils and equipment. For the purpose of this indicator, poisonings should be excluded, if possible. **Total population**: total resident population
Specification of data needed	Number of reported accidents in the home Total population
Data sources, availability and quality	Comprehensive data on physical injuries by accidents in the home are likely to be difficult to acquire, due to lack of referral or reporting. Many injuries may not be considered sufficient to be referred to the medical services; many others, though reported, may not be clearly classified as a result of an accident in the home. Probably the most useful source of data are hospital admissions statistics, though these tend to cover the more severe, acute injuries. Other potential sources include data from GPs and household surveys. Data on the total population should be available from national census statistics, and should be reliable.

Computation	The indicator can be computed as: 1000 * (A / P) where A is the total number of reported cases of injury by accidents in the home, and P is the total population.
Units of measurement	Number per thousand head of population
Scale of application	Local to international, though problems of data consistency and completeness limit application at broader scales..
Interpretation	This is a potentially useful indicator, which gives a general measure of injuries due to accidents in the home. Problems of data availability and quality, however, mean that care is needed in making comparisons between different areas or countries, or over long periods of time. Data are likely to be affected, for example, by ease of access to the medical services, and by differences in reporting procedures.

ACCESS TO BASIC SANITATION	RISK
INDICATOR PROFILE	
Hazard	Sanitation
Rationale and role	Access to adequate excreta disposal facilities is an important requirement if adverse health effects of poor sanitation are to be avoided. This indicator thus provides a measure of the health risk from exposure of the population to infectious agents associated with poor sanitation. The indicator can be used: • to assess and compare general levels of access to sanitation facilities, as a basis for priority setting; • as one of a group of indicators to assess levels of in social inequality and deprivation; • to assess and identify areas with poor sanitation, where specific policy action may be required; • to help investigate associations between sanitary conditions and specific health effects; • to help target and plan efforts to improve domestic sanitation and to monitor progress of such measures.
Alternative methods and definitions	The indicator can be defined as the percentage of the population (or of households) with (or alternatively without) access to adequate excreta disposal facilities. To apply this definition, a clear and appropriate definition is needed of what constitutes 'adequate excreta disposal facilities'. This needs to specify both the type of facility and its accessibility (e.g. whether in the home or outside). Definitions are likely to vary according to local circumstances (e.g. between developed and developing countries). Where data are available, the indicator could be further refined according to the type of facilities (e.g. connection to public sewerage system, cess-pit, pit latrines, facilities in house or outside).
Related indicator sets	UN *Indicators of sustainable development* • Basic sanitation: percent of population with adequate excreta disposal facilities WHO *Catalogue of health indicators* • Access to sanitary means of excreta disposal
Sources of further information	UN *1996 Indicators of sustainable development. Framework and methodologies*. Report for the UN Commission on Sustainable Development. New York, USA, UN Department for Policy Coordination and Sustainable Development. WHO 1981 *Development of indicators for monitoring health for all by the year 2000*. P. 29. Geneva: WHO. WHO 1982 *National and global monitoring of water supply and sanitation*. VWS series of Cooperative Action for the decade, No.2. WHO 1990 *Water supply and sanitation sector monitoring report (WSSMR)*. WHO/UNICEF Joint Monitoring Programme. WHO 1996 *Catalogue of health indicators: a selection of health indicators recommended by WHO Programmes*. Geneva: WHO.
Involved agencies	WHO-Programme for the Promotion Environmental Health.

EXAMPLE INDICATOR	
Definition of indicator	Percentage of the population with access to adequate excreta disposal facilities.
Underlying definitions and concepts	This indicator is based on the assumption that poor sanitary facilities increase the risks of infectious diseases such as diarrhoea and cholera. Underlying definitions are: • **Adequate excreta disposal facilities**: a facility which provides for the controlled disposal of human excreta in ways which avoid direct human exposure to faeces, or contamination of food and local water supplies by raw faeces. Suitable facilities might range from simple but effective pit latrines, to flush toilets with sewerage. All facilities, to be effective, must be correctly constructed and properly maintained. • **Access to adequate excreta disposal facilities**: people with excreta disposal facilities either in their dwelling or located within a convenient distance (<50 metres) from the user's dwelling. This thus includes the urban and rural populations served by connections to public sewers; household systems (pit privies, pour-flush latrines, septic tank, etc); communal toilets; and simple but adequate excreta disposal such as pit privies, pour-flush latrines, covered by latrines, etc • **Total population**: total resident population.
Specification of data needed	The number of people with access to adequate excreta-disposal facilities. Total population.
Data sources, availability and quality	Data on excreta disposal facilities may be available from relevant administrative authorities (e.g. public works, sanitary works or housing departments). In some countries, data are also available via national censuses. Where such sources do not exist or are inadequate, special surveys will be necessary. Data on total population are available from national censuses and should be reliable.
Computation	The indicator can be computed as: $100 * (P_e / P_t)$ where P_e is the number of people living in dwellings with access to adequate excreta disposal facilities, and P_t is the total population.
Units of measurement	Percentage
Scale of application	Local to international
Interpretation	The indicator can be interpreted directly to show the adequacy of domestic sanitary conditions, and thus the risks to health from exposures to infectious agents. A high percentage of people or households with access to adequate excreta disposal facilities should indicate a lower risk of exposure and adverse health effects; a low percentage would imply higher risks of exposure and infection. If compared to national targets, the indicator can similarly be interpreted to show progress towards achieving these goals. Nevertheless, some care is needed in interpreting the indicator, in particular because the availability of a facility does not always translate into their proper utilisation and improved hygiene. Data may also be of uncertain quality.

MUNICIPAL WASTE DISPOSAL	HAZARD
INDICATOR PROFILE	
Hazard	Waste handling
Rationale and role	The development of an effective service for domestic waste collection is one of the primary ways of improving living conditions in urban areas, of reducing pollution of surface water and groundwater, and of reducing exposures (especially of children) to hazardous substances and pathogens in waste materials. This indicator thus provides a measure of the hazard from waste handling. It can be used: • to assess and compare the extent and effectiveness of measures to collect and remove wastes and progress towards waste management objectives; • to identify areas with poor waste collection facilities, where special action is required; • as a measure of potential exposures to unhealthy living conditions or hazardous/ unsafe substances and pathogens in waste materials; • to help investigate relationships between exposures to waste and health effects.
Alternative methods and definitions	This indicator needs to define the amount or proportion of solid waste disposed of in a safe and controlled way by (or on behalf of) municipal waste management services. Several alternative methods are possible for this indicator. It may, for example, be based on either the mass of solid waste or the volume. Data are often more readily available in terms of mass, but volume measures have the advantage that they reduce the effects of moisture content at point of disposal, and may be more relevant in the case of landfill. The indicator can also be expressed either in absolute terms (tonnes, m^3), in per capital terms (amount/head of population) or proportional terms (percentage of all solid waste). Each of these will convey slightly different messages and should be used to address different issues. Absolute measures, for example, indicate the total amount of waste being disposed of, but do not show the extent to which this is matching rates of waste generation. Per capital measures are useful for comparisons between countries, and highlight areas which are relatively profligate in terms of waste generation. Percentage measures show the extent to which the collection service is matching waste generation, but gives no indication of the total amounts of waste involved. The indicator might also be related to a measure of GDP as the denominator; this standardises the indicator for level of affluence or development. A further alternative is to express the indicator in terms of the method of disposal (e.g. by landfill, incineration, recycling, reuse).
Related indicator sets	UN *Indicators of sustainable development* • Municipal waste disposal • Waste recycling and reuse • Household waste disposal per capita
Sources of further information	UN *1996 Indicators of sustainable development. Framework and methodologies*. New York: UN. WHO 1981 *Development of indicators for monitoring health for all by the year 2000*. Geneva: WHO. WHO 1981 *Global strategy for all by the year 2000*. Geneva: WHO WHO 1982 *National and Global monitoring of water supply and sanitation.* CWS series of Cooperative Action for the Decade, No.2. WHO 1990 *Water supply and sanitation sector monitoring report (WSSMR*). WHO/ UNICEF Joint Monitoring Programme. WHO 1994 *Ninth general programme of work covering the period 1996-2001*. Geneva: WHO.

Involved agencies	WHO UNCHS (Habitat) UNEP National/regional waste authorities and companies Local authorities
EXAMPLE INDICATOR	
Definition of indicator	The mass of solid waste disposed of safely by municipal waste management services
Underlying definitions and concepts	The indicator is based on the assumption that controlled waste collection and disposal helps to reduce exposures of the population to materials likely to have adverse effects on health, and improve the quality of the living environment. Underpinning definitions are: • **Municipal solid waste:** Waste materials produced and discarded by households and other municipal establishments (e.g. schools, offices, hospitals, hotels). The waste material is likely to be primarily non-hazardous, but may include small amounts of hazardous material. • **Amount of safely disposed waste**: the mass of controlled disposal or treatment of waste, which removes it from the open environment (e.g. by landfill, incineration, composting, recycling or reuse). • **Total population:** total resident population.
Specification of data needed	Amount of waste disposal by municipal waste authorities. Total population.
Data sources, availability and quality	Data on the amount of disposed waste are occasionally available through routine monitoring undertaken by the waste management companies or local authorities (e.g. using weighbridges at disposal sites). More commonly, however, data need to be derived from special surveys. In both cases, data tend to be highly uncertain, due to problems of ensuring accurate measurement, variations in the unit weight of the wastes (e.g. due to differences in moisture content), and ineffective reporting by the agencies concerned. Data on the total population are available from national censuses and should be reliable.
Computation	The indicator can be computed as: M_w / P where M_w is the mass of waste disposed of, and P is the total population.
Units of measurement	Tonnes per annum per capita.
Scale of application	Local to international, though at broader scales interpretation is limited by problems of data consistency and completeness.

Interpretation	The volume of waste disposed by the municipality is an indicator which is related to the efficiency and level of service provision for waste management. Generally, adequate waste management indicates that the authorities are aware of the preventative nature and reduction of important health and environmental risks resulting from poor waste management. If this waste disposal indicator is compared with waste generation rates, it will give some indication of both the amounts of waste that are dumped indiscriminately and that recycled and reused by the informal and formal sectors. In developing countries, service provision often cannot keep up with demand, and it can be assumed that there will be significant room for improvement. In more developed countries, where service provision is not such a problem, the indicator might better be replaced by a measure of the proportion of the waste generated by human settlements that is not recycled or re-used. As with all statistics on waste generation and disposal, this indicator faces severe problems of data accuracy. Major errors often exist in these statistics (often of several orders of magnitude), largely because of the difficulties of measuring waste disposal and the poorly developed monitoring systems which exist in most countries. Trends or patterns shown by the indicator thus need to be interpreted with the utmost caution. Moreover, disposal – especially in landfill - may not effectively remove the waste from human contact, unless the sites are properly managed and seepage into the environment is controlled. In addition, the mass (or volume) of total waste disposed of is not necessarily a reliable measure of the risk to health; in many cases, the main risks come from the relatively small component of hazardous wastes. It is the way in which these are disposed of which is often most important.

MUNICIPAL WASTE COLLECTION	RISK
INDICATOR PROFILE	
Hazard	Waste handling
Rationale and role	The development of an effective service for domestic waste collection is one of the primary ways of improving living conditions in urban areas, of reducing pollution of surface water and groundwater, and of reducing exposures (especially of children) to hazardous substances and pathogens in waste materials. The indicator provides a measure of the health risk associated with exposure to domestic wastes. It can be used: • to assess and compare the extent and effectiveness of measures to collect and remove wastes and progress towards waste management objectives; • to identify areas with poor waste collection facilities, where special action is required; • as a measure of potential exposures to unhealthy living conditions or hazardous/ unsafe substances and pathogens in waste materials; • to help investigate relationships between exposures to waste and health effects.
Alternative methods and definitions	This indicator can be defined as the percentage of households served by regular waste collection services. Alternatively it could be expressed as the proportion of population served by regular municipal waste removal services, where data on the number of persons per household are available. This has a significant advantage, in that waste collection services often preferentially serve more affluent areas, with lower occupation densities; higher density housing may thus be under-represented.
Related indicator sets	UN *Indicators of sustainable development* • Municipal waste disposal • Waste recycling and reuse • Household waste disposal per capita
Sources of further information	IMO 1995 *Global waste survey*. International Maritime Organization, Final Report. ISWA 1996 *Solid waste management for economically developing countries*. Copenhagen: International Solid Waste Association. UN 1996 *Indicators of sustainable development. Framework and methodologies*. New York: UN. UNEP & IETC 1996 *International source book on environmentally sound technologies for municipal solid waste management*, Technical Publication Series (6): Osaka/Shiga, Japan. WHO 1995 *Solid waste management in some countries of the Eastern Mediterranean Region*, CEHA Document, No. Special studies, SS-4, Amman: CEHA. WHO 1995 *Waste collection*. Copenhagen: WHO regional office for Europe. WHO 1995 *Solid waste and health*. Copenhagen: WHO regional office for Europe.
Involved agencies	WHO UNCHS (Habitat) UNEP National/regional waste authorities and companies Local authorities
EXAMPLE INDICATOR	
Definition of indicator	Percentage of households served by regular waste collection services.
Underlying definitions and concepts	The indicator is based on the following definitions: • **Solid waste:** solid materials which have no further useful purpose and are thus discarded. • **Regular waste collection service:** a regular and frequent service which collects and safely disposes of domestic waste from the door or a designated waste collection site. The frequency of collection should be such that it avoids the accumulation of uncontained rubbish. • **Household:** a single dwelling unit (e.g. a house or apartment) intended for permanent residence.

Specification of data needed	Total number of households covered by the waste collection service. Total households in the area of study.
Data sources, availability and quality	Data on the number of households covered by the waste collection services may be available from local authorities or from the waste collection agencies. Often, these data will be collated at national level by national statistical offices or by the relevant ministries. Data on the total number of households should be available through national census statistics, though care is needed in relation to the definition of a 'household' (e.g. how collective dwellings are classified). Alternatively, data can be collected via household or special surveys.
Computation	The indicator can be computed as: (W / H) * 100 where W is the number of households covered by the waste collection service; and H is the total number of households in the area.
Units of measurement	Percentage
Scale of application	Local to international.
Interpretation	This indicator provides a measure of the extent to which waste removal services are adequate to avoid health risks. As such, an increase in the proportion of households covered by the waste collection service may be interpreted as evidence of increased action, and reduced health risks; a reduction in the proportion covered would imply that action was unable to keep up with need, and a heightened health risk. For various reasons, however, the indicator needs to be interpreted with caution. The main problem concerns the reliability of the data, especially in remote or rural areas. The existence of a waste collection service, also, does not necessarily mean either that it operates effectively, or that the waste is then disposed of safely.

	RISK
INDICATOR PROFILE	
Hazard	Industrial pollutants Occupational accidents
Rationale and role	Hazards in the occupational environment are a major cause of injury, ill health and death. These hazards arise from a number of sources: from poorly guarded or designed machinery, from unsafe working practices, from the use of hazardous substances or materials, from poor ventilation and environmental control in the workplace, and from a wide array of everyday accidents. These types of working environment tend to be most common in small, informal workshops and domestic workplaces, but may also occur in many larger premises in some sectors. This indicator provides a measure of the risks associated with exposure to such hazards in the workplace. Because of limitations of data it is mainly applicable at a local scale, where it might be used: • to monitor levels of occupational exposure in the workplace; • to monitor the effects of technological or other changes on workplace exposures and their potential health risks; • to identify specific occupations and workplace settings which pose hazards for workers, as a basis for targeting action; • to assess levels of compliance with health and safety or other legislation aimed at improving working practices and protecting workers; • as part of epidemiological studies to investigate relationships between occupational hazards and health effects.
Alternative methods and definitions	Assessment of exposures to unsafe working environments poses enormous problems, both because of the difficulties of defining what is 'safe' and 'unsafe' and in obtaining the relevant data. For this reason, this indicator can realistically be applied mainly at the local level; at broader scales, it can be used only in a general and qualitative manner. Where suitable data are available the indicator might be expressed either as the number of workers exposed or as the percentage of workers exposed. Each conveys a somewhat different message and might be used to address different questions. The total number of workers helps to identify those work places or practices which pose the greatest threat to health and gives a measure of the overall occupational health risk. For long term monitoring, however, it is susceptible simply to changes in the number of people employed, and as such may vary more due to economic factors than positive intervention. The percentage of the work force exposed may therefore be more useful when examining long-term effects of health and safety measures. Where possible, the indicator should be compiled and presented separately for different employment sectors, for different sizes of workplace, and for different types of hazard. This would help to identify more clearly the sources of exposure and those most at risk. In some cases, a more rigorous alternative to this indicator may be possible: the actual levels of exposure to specific workplace pollutants. This might be assessed by micro-environmental monitoring in the workplace, by personal monitoring (as occurs for radioactivity) or by use of biomarkers (e.g. analysis of hair, urine or blood samples).
Related indicator sets	None
Sources of further information	
Involved agencies	WHO National health and safety executives

EXAMPLE INDICATOR	
Definition of indicator	Percentage of workers exposed to unsafe, unhealthy or hazardous working conditions
Underlying definitions and concepts	This indicator requires the ability to identify, and measure the extent of, unsafe, unhealthy or hazardous workplaces, and the number of people employed therein. Definitions of such workplaces are likely to vary substantially, both between different countries and between different industries. Characteristics of unsafe, unhealthy or hazardous working conditions might include: • work which involves open exposure to hazardous substances or materials (e.g. chemicals); • work involving the unprotected use of dangerous machinery or equipment (e.g. saws, lathes, crushing equipment, motor vehicles); • work which involves operation in dangerous places (e.g. at height or below water) without adequate safety equipment; • workplaces which have poor environmental control (e.g. for air pollution, heat, light, noise); • workplaces which are over-crowded or physically badly laid out; • workplaces which lack adequate facilities for fire prevention or control; • workplaces in which unsafe or unhealthy working practices are carried out (e.g. highly repetitive physical work, stressful working environments). In addition, a definition is required of the total number of workers: i.e. people carrying out, or employed in, a trade or business.
Specification of data needed	Number of people working in unsafe, unhealthy or hazardous workplaces. Total number of workers.
Data sources, availability and quality	Data on the number of people working in unsafe, unhealthy or hazardous workplaces are not usually collected in any routine way. Estimates thus have to be made either from specially designed surveys, or by extrapolation from previous studies. In both cases, care is needed because studies and surveys tend to be targeted at workplaces which are known or suspected to be unhealthy or unsafe; available data may thus contain considerable bias. Data on the total number of workers are usually available from national employment statistics or from company records. Such statistics, however, tend to omit those employed in informal or casual work or who have multiple (and often unregistered) jobs.
Computation	The indicator can be computed as: $100 * (H / W)$ where H is the number of people working in unsafe, unhealthy or hazardous housing and W is the total number of workers.
Units of measurement	Percentage
Scale of application	Mainly local
Interpretation	Interpretation of the indicator must be undertaken with utmost care. The varied nature of occupational hazards, and the lack of any formal classification of hazards in the workplace, mean that definitions of what constitutes an unsafe, unhealthy or hazardous workplace are likely to vary greatly from country to country (and probably from one industrial sector to another). Estimates of the number of people working in these environments are also prone to considerable uncertainty due to the informal nature of much employment, and the lack of routine monitoring. Levels of exposure are also likely to vary greatly over time, due to changes in work activity, and between individuals (due to differences in work behaviour and practice). Even the total number of workers may be subject to significant error in some cases. In addition, it is important to recognise the implications for such interpretations of expressing the indicator in a percentage form; this may mask large industries or workplaces with small proportions, but large numbers, of exposed workers.

INCIDENCE OF OCCUPATIONAL INJURY	HEALTH IMPACT
INDICATOR PROFILE	
Hazard	Industrial pollutants Occupational accidents
Rationale and role	Occupational hazards are a major cause of ill health throughout the world. Major sources of health risk are exposures to physical dangers (e.g. accidents at work), and the effects of physically stressful working conditions. These may result in either acute or chronic occupational injuries. This indicator is intended to provide a general measure of the health impact of occupational injuries. As such, it can be used: • to monitor trends in occupational injury rates; • to make inferences about changes in the extent of physically hazardous working environments (e.g. as a basis for policy development); • to identify physically hazardous occupations or working environments, where specific action may be needed; • to assess the effectiveness of occupational health and safety legislation or other interventions (e.g. awareness raising campaigns); • to help raise awareness about the need for safe working practices and a healthy workplace; • to analyse associations between occupational working conditions and ill health.
Alternative methods and definitions	This indicator can simply be defined as the incidence rate of occupational injuries within the total workforce. As such, it includes all reported physical injuries which require medical attention. The indicator can also usefully be measured and presented separately for different occupations (e.g. based on standard employment sector classifications), different classes of illness and by gender. Where there are a large number of part-time workers, use of 'total number of workers' may be inappropriate; instead, it may be more meaningful to base the indicator on the 'total number of worker years'. Problems with data availability mean that many variations on the indicator are possible, and may be necessary (e.g. by basing the indicator on different categories of illness). The definitions used need to be clearly stated in every case. Where other data are not available, a proxy can be used based on 'number of days off work'. This, however, is likely to include causes of illness other than occupational morbidity.
Related indicator sets	None
Sources of further information	WHO 1995 *Global strategy on occupational health for all*. Geneva: WHO.
Involved agencies	WHO ILO National health and safety agencies
EXAMPLE INDICATOR	
Definition of indicator	Incidence of occupational injury
Underlying definitions and concepts	This indicator requires the ability to identify cases of occupational injury due to accidents or inappropriate working conditions and practices. Underlying definitions are: • **Occupational injury**: a physical injury, requiring medical treatment, occurring at, or as a direct result of, work. • **Total number of workers**: the number of people carrying out, or involved in, a trade or business.

Specification of data needed	Number of cases of occupational injury Total number of workers
Data sources, availability and quality	Data on occupational injuries are available in many countries through routine reporting in accordance with employment or health-and-safety legislation (though considerable under-reporting tends to occur). Where these data are not available, they may need to be obtained from special surveys (e.g. using questionnaire techniques or by analysing company records). Such surveys may be subject to considerable inaccuracy, due to poor recording of worker injuries by the companies, and biased or incomplete recall and attribution of injuries by workers. Data on the total number of workers are usually available from national employment statistics or company records. Such statistics, however, tend to omit those employed in informal or casual work or who have multiple (and often unregistered) jobs.
Computation	The indicator can be computed as: $1000 * (M_o / W)$ where M_o is the total number of reported cases of occupational injury reported in the target workforce, and W is the total number of workers.
Units of measurement	Number per thousand workers.
Scale of application	Local to international, though problems of data consistency and availability may limit interpretations at broader scales.
Interpretation	Where reliable and consistent data are available, this indicator provides a potentially useful measure of the health risks associated with the occupational environment. In these situations, an increase in the level of work-associated morbidity may be used to infer a deterioration in the quality of the working environment; a reduction in the number of deaths may imply an improvement. For various reasons, however, this simple association will rarely apply. Problems of attributing illnesses to workplace exposures or injury, for example, mean that most estimates will be subject to considerable margins of error, especially in the case of effects with long latency times or non-specific causes. Problems in accurately quantifying the number of workers (or total number of worker years) may add to this uncertainty. Changes in the total number of people employed may also affect the rate, even though the total number of people subject to work-related illness or injury may not change.

MORTALITY FROM OCCUPATIONAL HEALTH HAZARDS	HEALTH IMPACT
INDICATOR PROFILE	
Hazard	Industrial pollutants Occupational injury
Rationale and role	Occupational hazards are a major cause of death throughout the world. Hazards include physical dangers (e.g. accidents at work), exposures to dangerous substances (e.g. chemicals, organic pathogens), and the effects of stressful working conditions. Exposures to these hazards may be either acute or chronic exposures, and death may occur either swiftly or after a considerable latency period. This indicator is intended to provide a general measure of the health impact of occupational exposures. As such, it can be used: • to monitor trends in occupational mortality rates; • to make inferences about changes in the level of safety of working environments (e.g. as a basis for policy development); • to identify high-risk occupations or working environments, where specific action may be needed; • to assess the effectiveness of occupational health and safety legislation or other interventions (e.g. awareness raising campaigns); • to help raise awareness about the need for safety in the workplace; • to analyse associations between occupational working conditions and mortality.
Alternative methods and definitions	This indicator can be defined as the death rate across the workforce due to occupational health hazards. As such, it comprises deaths due to both acute and chronic exposures. Where data permit, it can usefully be measured and presented separately for different occupations (e.g. based on standard employment sector classifications), different causes of death, and by gender. Where there are a large number of part-time workers, use of 'total number of workers' may be inappropriate; instead, it may be more meaningful to base the indicator on the 'total number of worker years'. Problems with data availability mean that many variations on the indicator are possible, and may be necessary (e.g. by basing the indicator on different categories of cause of death). The definitions used need to be clearly stated in every case.
Related indicator sets	None
Sources of further information	WHO 1995 *Global strategy on occupational health for all.* Geneva: WHO.
Involved agencies	WHO ILO National health and safety agencies
EXAMPLE INDICATOR	
Definition of indicator	Mortality from occupational health hazards

Underlying definitions and concepts	This indicator requires the ability to identify cases of mortality due to accidents or exposures in the workplace, including: • acute exposure to hazardous substances or materials (e.g. chemicals or organic pathogens); • chronic exposure to hazardous substances of materials (e.g. due to poor environmental control or lack of adequate worker protection) • accidents and physical injury in the workplace (e.g. due to poorly guarded or unsafe equipment, work in dangerous places, fire, or poor working practices); • stress due to working in a psychologically unhealthy environment (e.g. highly repetitive work, bullying, excess levels of responsibility). The indicator also requires the definition of the total number of workers: i.e. those carrying out, or involved in, a trade or business.
Specification of data needed	Number of deaths due to occupational health hazards Total number of workers
Data sources, availability and quality	Data on acute occupational mortality (e.g. due to injuries at work) are generally available through notification systems (e.g. under health and safety legislation). These provide generally reliable data on mortality from accidents in the formal workplace. However, they do not usually include mortality due to chronic occupational exposures, nor are they likely to be accurate for the unregistered work sector. Cause specific mortality data are also available from vital registration statistics. Problems with these data occur in this context, however, because they do not necessarily, nor consistently, report the source of the exposure or injury leading to death. Thus, accurate identification of occupational, as opposed to other, causes of death is rarely possible. This problem is especially severe in the case of diseases with long latency times (such as cancer), and with causes of death which are non-specific (e.g. some cancers, cardio-vascular problems). For these reasons, this indicator may need to be based upon a restricted range of sentinel diseases and injuries, for which direct occupational causes can be reliably specified (e.g. asbestosis, silicosis, death due to injury at work). Data on the total number of workers are usually available from national employment statistics or company records. Such statistics, however, tend to omit those employed in informal or casual work or who have multiple (and often unregistered) jobs.
Computation	The indicator can be computed as: $1000 * (M_o / W)$ where M_o is the total number of deaths due to occupational health hazards and W is the total number of workers.
Units of measurement	Number per thousand workers.
Scale of application	Local to international, though problems of data consistency and availability may limit interpretations at broader scales.
Interpretation	Where reliable and consistent data are available, this indicator provides a useful measure of the health risks associated with the occupational environment. In these situations, an increase in the number of work-associated deaths may be used to infer deterioration in the level of safety in the workplace; a reduction in the number of deaths may imply an improvement in workplace safety. For various reasons, however, this simple association will rarely apply. Problems of attributing deaths to workplace exposures or injury, for example, mean that most estimates will be subject to considerable margins of error, especially in the case of effects with long latency times or non-specific causes. These margins of error should be clearly stated when this indicator is used. Problems in accurately quantifying the number of workers (or total number of worker years) may add to this uncertainty. Changes in the total number of people employed may also affect the rate, even though the total number of people killed at work may not change.

MORTALITY FROM MTOR VEHICLE ACCIDENTS	HEALTH IMPACT
INDICATOR PROFILE	
Hazard *Rationale and role*	Traffic accidents Motor vehicle accidents continue to be a major cause of death and injury throughout the developed world, and are increasing in many developing countries. Marked differences in rates of mortality due to road traffic accidents are also seen between countries, apparently reflecting variations in road and vehicle safety, driving behaviour, environmental conditions and performance of the emergency and health services. This indicator provides a measure of the health impact from non-occupational injury. Potential applications include: • Monitoring trends in traffic accident deaths, in order to help prioritise policy and management needs. • Mapping the distribution of road traffic deaths, in order to identify local or regional hotspots, and to identify areas in need of special action. • Comparing the effectiveness of emergency services and hospital treatment of road traffic victims. • Assessing the effectiveness of interventions - e.g. traffic management, public transport schemes, road improvements, vehicle safety measures or educational initiatives - on road traffic deaths. • Assessing the effects of changes in travel behaviour (e.g. a modal shift from car to public transport, or changes in attitudes and behaviour regarding drinking and driving) on road traffic deaths. • Analysing relationships between road traffic volumes and traffic accident mortality.
Alternative methods and definitions	This indicacor can be defined as the death rate due to road traffic accidents. Where appropriate, the indicator might be usefully standardised both by age- and gender and subdivided according to travel mode - e.g. motor vehicle (car, truck, bus, rail, air), bicycle and pedestrian. In many cases, children and young adult men are the most common victims of road traffic accidents; deaths amongst pedestrians also tend to outnumber those of car drivers or passengers. The indicator can be presented either in absolute terms (e.g. total number of deaths), as a population rate (e.g. number of deaths per thousand people), in terms of the total traffic volume (e.g. vehicle kilometres travelled) or in terms of the number of trips. Each will convey a somewhat different meaning and suffers from different problems of interpretation. Data on the absolute numbers of deaths, for example, make no allowance for differences in population, and thus should not be used for comparisons between different areas or countries. Rates based on the population number take account of changes or differences in population size, but do not reflect differences in traffic conditions (e.g. traffic volumes or speed). Indicators based on traffic volume or number of trips provide a means of assessing driver/traffic safety, but do not indicate the size of the public health problem. The indicator thus needs to be constructed differently, according to its intended purpose.
Related indicator sets	Brown, L. *Vital signs* • Traffic accidents
Sources of further information	WHO European Centre for Environment and Health 1997 *Atlas of mortality in Europe*. Subnational patterns 1980/1981 and 1990/1991. Bilthoven: WHO Regional Publications, European Series. No. 75. Brown, L. 1996 *Vital Signs* W.W. Norton and Company, New York.
Involved agencies	National transport ministries and local/regional highways authorities WHO
EXAMPLE INDICATOR	
Definition of indicator	Death rate due to road traffic accidents

Underlying definitions and concepts	The indicator is based on the following definitions: • **Deaths due to road traffic accidents:** all deaths directly or indirectly attributable to involvement in a motor vehicle traffic accident, however caused. This includes deaths of vehicle drivers, passengers and pedestrians/cyclists. It also includes both immediate and delayed deaths (though the latency period is rarely clearly defined). This definition is based on the assumption that data on cause of death defines the source of the injury. • **Total population:** total resident and visiting population. (Note: for this indicator the total resident and visiting population is more appropriate as the denominator, since many deaths in road accidents occur to tourists or other visitors.)
Specification of data needed	Total number of deaths due to road traffic accidents (ICD E810-E819) Total resident and visiting population
Data sources, availability and quality	Data on deaths due to road traffic accidents should be available at the national level from official statistics, and at the regional/local level from either registrations of cause of death or from police statistics. These statistics have a number of weaknesses, including the way in which cause of death is defined (reference may be made only to the nature of the injury causing death, not its source), the method of geocoding (individuals will usually be defined by place of residence, not the location of the accident), and lack of distinction between deaths of pedestrians and vehicle users. Data on total resident population should be available from national censuses and should be reliable. Some census statistics also provide a measure of the number of temporary residents (i.e. visitors) at the time of survey, though definitions tend to vary between countries, and the data may not be representative of the number of visitors at other times in the year. Where appropriate, separate estimates of the number of visitors may be obtained from tourist statistics.
Computation	The indicator can be computed as: $1000 * (M_t / P)$ where M_t is the total number of deaths due to traffic accidents and P is the total population.
Units of measurement	Number per thousand head of population.
Scale of application	Local to international, though problems of data consistency and availability may limit interpretations at broader scales.
Interpretation	This indicator is in general relatively easy to interpret, in that the link between cause and health effect is explicit. Changes in the indicator may nevertheless imply different processes. For example, a reduction in the mortality rate may be due, inter alia, to: a reduction in total traffic volume, reduced traffic speeds (e.g. due to increased congestion), an improvement in road design, improved traffic management, improvements in vehicle safety, improvements in driver behaviour, improved environmental conditions (e.g. weather), fewer pedestrians or cyclists, greater segregation of pedestrians from road traffic, improved emergency services, or improved health services. Problems inherent in the data also need to be considered, especially where different countries or regions, with different reporting systems, are being compared. Difficulty also exists in allowing for the number of visitors (especially in transit), which may be significant in some areas.

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