DECISION-MAKING IN ENVIRONMENTAL HEALTH

FROM EVIDENCE TO ACTION

EDITED BY C. CORVALÁN, D. BRIGGS AND G. ZIELHUIS

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WORLD HEALTH ORGANIZATION

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FOREWORD

This book evolved from the need to address a number of fundamental questions relating to environmental health for which there were no simple answers. These questions ranged in scope and depth, from issues related to basic statistics on health and the environment to the use of information in the management of problems associated with environmental health. Many of these questions were concerned with the way in which information is, or can be, used to help address environmental health problems, and with the role and value of environmental health indicators. Examples of these questions are:

How can one collect and present information which is useful in shaping and making decisions at the local level?

What does a national indicator (e.g. infant mortality rate or access to water and sanitation) mean in the face of large disparities at the sub-national level?

Why is it not always possible to quantify indicators at the sub-national level, if national-level indicators exist?

What do environmental exposure indicators mean beyond the local level, where people are affected?

Such questions indicate a need to address issues relating to the requirements and use of local-level information. Other questions were of a more technical nature, for example:

What is the health impact in terms of morbidity and mortality of a given environmental exposure?

How does the impact vary according to age, gender, geographical location and socio-economic group?

How are environmental health problems ranked and prioritised at the local level?

Further questions referred to policy and decision-making issues, for example:

How does the environmental health decision-making process operate locally?

How are locally collected data transformed into information and used in decision-making, or if such information is not used, what are the reasons?

This book addresses these and other related issues. It proposes a model for decision-making in environmental health based on the involvement of relevant stakeholders and the use of scientifically sound data and appropriate analytical methods. It also proposes a framework for understanding environmental health problems and their effects in a manner that allows interdisciplinary and intersectoral approaches to action. Finally, the book recommends the development of local environmental health information systems for the collection of locally relevant data, with emphasis on simplification to avoid overloading such systems.

The link between the environment and human health has been suspected for centuries; there is now widespread consensus that healthy environments are prerequisites for human existence and health. However, the link between development activities and their impact on health and the environment is a more recent issue. At the Earth Summit, held in Rio de Janeiro in 1992, it was recognised that both insufficient development, leading to poverty, and inappropriate development, leading to over-consumption, could result in severe environmental health problems. In all countries, information about health and the environment at different levels (e.g. village, city, province or country) is necessary in order to support the management and decision-making process in relation to environmental health. Providing relevant information, in a form that all those involved can understand and accept, within the constraints of time and other resources, is thus a major challenge. It is not simply a matter of collecting data. In order to be useful, environmental health information should be pertinent, and sufficiently accurate and usable by all those involved in decision-making, from the public to political leaders. The decision-making process requires information that is directly relevant to the task in question, the translation of this information into a consistent and coherent form, and the presentation of the information in a manner that is appropriate and acceptable to the different users. This book addresses these issues in detail.

This book will be useful to researchers in public health, epidemiology and the social sciences. It will also be useful to those working in government institutions concerned with environmental health, particularly those responsible for collecting and analysing data as part of local or national information systems.

World Health Organization

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Chapter 1*

HEALTH AND ENVIRONMENT ANALYSIS

1.1 Background

Human exposure to pollutants in the air, water, soil and food — whether in the form of short-term, high-level, or long-term, low-level exposure — is a major contributor to increased morbidity and mortality. However, the disease burden attributable to these exposures is not known with any degree of certainty because levels of general environmental pollution fluctuate greatly, methods for analysing the relationships are incompletely developed, and the quality of available data is generally poor. Precise measures of the association between pollution levels and health outcomes are therefore rare. Exposure to environmental pollution is also usually involuntary. People may be unaware of this and/or its possible effects; as a result they may exert little control over their risk of exposure. Biological and chemical agents in the environment are nevertheless responsible for the premature death or disablement of millions of people worldwide every year (WHO, 1992). It has recently been estimated that almost one quarter of the global burden of disease is attributable to environmental factors (WHO, 1997). This estimate, which is based on published data (Murray and Lopez, 1996), was made by attributing an environmental causal fraction to each disease category with a known environmental link. The ability to link health and environmental data, and thereby to determine the relationship between levels of exposure and health effects, is clearly vital to control exposure and protect health. Decision-makers need information on the health effects attributable to environmental pollution in order to assess the implications of their decisions, to compare the potential effects of different decisions and choices, and to develop effective prevention strategies.

Standards and guidelines against which to assess levels of environmental pollution are now widely available. For example, the World Health Organization (WHO) has developed environmental quality guidelines for various pollutants in the air (WHO, 1987), drinking-water (WHO, 1993),

* *This chapter was prepared by C. Corvalán, T. Kjellström, G. Zielhuis and D. Briggs*

food (FAO/WHO, 1989) and workplace (e.g. WHO, 1980, 1986). These guidelines are based on epidemiological and toxicological studies and indicate the maximum environmental levels, or the maximum levels of human exposure, considered acceptable in order to protect human health. Nevertheless, individual susceptibility to pollution varies, to the extent that it is possible that some individuals may experience adverse effects at levels below the maximum recommended levels. Moreover, in many areas of the world these levels are frequently exceeded, in some places by as much as several times the recommended levels, and reduction of human exposure may be difficult or very costly. Adverse effects on human health are therefore likely to continue to be observed in these areas. In such situations, analysis of data on human health and the environment provides a valuable tool for obtaining estimates of the health impact of pollution, which can be used to set priorities for action.

Many epidemiological studies have been undertaken to analyse the relationship between specific forms of environmental pollution and health effects. Most of these studies have been conducted in developed countries, and the methods used may not be applicable to other settings, especially if high quality data are unavailable or too expensive to collect. Major problems often exist in obtaining data on health and particularly on environmental exposure at the individual level. As a consequence, it is normally necessary to rely on so-called "ecological" methods, in which the statistical unit of observation is a population rather than an individual (Rothman, 1986; Beaglehole *et al.*, 1993; see Chapter 6).

A serious limitation in conducting epidemiological studies concerns the measurement of exposure in individuals. Routinely collected environmental data are widely available in most countries and, where relevant, can be used as a proxy for exposure data. For example, monitoring networks provide data on pollution levels at specific sites, which can be used to characterise average exposures for geographical regions. Environmental data are also often compared with guideline values or maximum recommended levels in order to determine levels of compliance with prevailing policies. The data are, however, rarely used to quantify the potential health effects. Equally, although many countries routinely collect data on health outcomes in the form of morbidity and mortality statistics, attempts are rarely made to link the data to environmental or other factors in order to attribute outcomes to their cause.

1.2 Tools for analysis and interpretation

Linking environmental and health data offers considerable benefits, but also poses many dangers if not carefully carried out. In linking such data it is all too easy to overlook the statistical problems and inconsistencies of the different data sets, or to misinterpret their apparent relationships. Valid linkage thus relies on the use of both valid data and appropriate linkage methods.

Numerous methods for data linkage have been developed in many different areas of application. Their suitability for linking environmental and health data, however, is often limited and always needs to be assessed carefully. Two important criteria must be considered in this context. First, the methods must be politically acceptable. This means that they must be simple, inexpensive to implement, and operable with the available data, thus allowing rapid assessment. If the methods are overly complex, requiring extensive resources and collection of large amounts of additional data, few developing countries will be able to apply them, and even in developed countries their use may be costly and result in delays in action. Second, if the results are to be accepted as a basis for action, the methods must be scientifically credible and statistically valid. This means that they should be accurate, sensitive to variations in the data of interest and unbiased. Simple, crude methods should produce results that agree with those obtained from more detailed studies, for which the statistical precision can be quantified.

In practice, these requirements are rarely met in full. If they were, there would hardly be a need for individual-level studies. Nevertheless, simple methods may still have considerable value. Results from ecological studies, for example, are useful if the potential biases can be identified, evaluated and shown to be small. At the very least, the results should help to identify areas or issues requiring more detailed investigation. Countries where detailed, individual-level studies have not been performed also urgently need access to methods which can help to shed light on the extent and health effects of specific forms of environmental pollution. Priority should be given to the development of research capabilities in developing countries for this purpose (Environmental Research, 1993).

Where detailed information on the exposure–response relationship of specific pollutants is available, Quantitative Risk Assessment (QRA) techniques, based on epidemiological data, can be used to estimate the impact of exposure on different populations without the need for new substantive research (for further information, see Romieu *et al.*, 1990; Nurminen *et al.*, 1992; Ostro, 1996). This implies knowledge about exposure, the population at risk and the health effects associated with exposure in the form of a dose–response function derived from epidemiological studies (i.e. pooled study results) (Goldsmith, 1988; Smith, 1988; Hertz-Picciotto, 1995; Smith and Wright, 1995; Wartenberg and Simon, 1995). Because of limitations in available research data, QRA can often be applied only by extrapolating study results from one country (usually developed) to other countries (usually less developed). The fact that the range of exposure levels and the distribution of other conditions likely to affect health outcomes may differ substantially between populations inevitably limits the validity of this approach. In addition, assessments can only be carried out reliably for pollutants for which well researched exposure–response relationships have been established. Even then, uncertainty regarding the assumed association between environmental pollution levels and the actual exposures in individuals is a major constraint.

QRA remains the only tool available for estimating the health outcomes of environmental pollution in areas where health monitoring is not undertaken, or where the quality of the data collected is poor. It is also the only feasible approach for obtaining crude estimates of health impacts in very large population groups. The development and application of well tested methods of risk assessment is therefore an important priority. It is equally important to describe the risks of exposure which exist to decision-makers and the community in a meaningful way (Rose, 1991).

1.3 Health and Environment Analysis for Decision-Making Project

The Health and Environment Analysis for Decision-Making Project (HEADLAMP) (Corvalán and Kjellström, 1995) is aimed at addressing some of the limitations outlined above in the information currently available to support environmental health policies. Its overall purpose is to make valid and useful information on the local and national health impact of environmental hazards available to decision-makers, environmental health professionals and the community, in order to promote effective action to prevent or reduce environmental health problems. To this end, it is designed to indicate environmental health trends, as a basis for defining appropriate policies and for assessing the value and performance of these policies over time. It also aims to encourage local and national capacity-building, as a means of enabling environmental health issues to be tackled more effectively at the appropriate level.

HEADLAMP takes a deliberately interdisciplinary and intersectoral approach. It uses a combination of methods from environmental epidemiology (including human exposure assessment) and other health and environmental sciences to produce and analyse data, to convert these data into information, and to present this information so that it can be understood and acted upon by those responsible for environmental health protection. Three principles define the HEADLAMP process:

1. HEADLAMP is based on scientifically established relationships between environmental exposure and health effects. This approach has proved successful in surveillance systems for the prevention and

control of occupational diseases, and has been shown to be most effective when based on a sound set of data relating to both exposure and health outcomes (Thacker *et al.*, 1996).

2. HEADLAMP makes use of environmental health indicators to assess and monitor the environmental health situation, to help define the actions which need to be taken, and to inform those concerned. The indicators are chosen according to the issue requiring investigation, which in turn determines the data and method needed. The development of appropriate environmental health indicators is clearly integral to the HEADLAMP approach.
3. As far as possible, HEADLAMP uses routinely collected data. A major advantage of this approach is its cost-effectiveness. Data collection is expensive, and it is therefore important to obtain the maximum value from data through their repeated and effective use. To measure the relevant environmental health indicators, it may also be necessary to collect additional data. In these situations HEADLAMP encourages the use of appropriate, low-cost techniques.

The key to HEADLAMP is clearly information. Attempts to use information to support health intervention and policy are not new. Current health information systems, however, have been criticised because of the extra demands they impose on health workers, their tendency to centralise information (often in ways which make it inaccessible to many potential users), the failure to analyse adequately the collected data for use in planning, the aggregation of data which masks areas where action is required, and the failure to build links with other sectors (de Kadt, 1989). HEADLAMP is designed to avoid these weaknesses and limitations. It brings together not only the different sectors but also the many different stakeholders involved, including the community and local decision-makers. It builds upon existing health and environmental information systems and promotes the use of existing data, thereby allowing a feedback process to data collectors regarding its quality and the need for additional data. It also encourages data to be translated into information which can be used by different stakeholders and can act as an aid to decision-making. Moreover, HEADLAMP operates at the local level, avoiding problems of information centralisation and aggregation at higher levels. Through the implementation of the Programme of Action for Sustainable Development (Local Agenda 21) (United Nations, 1993), local governments are likely to take the lead role on environmental health at the local level (Williamson, 1996). HEADLAMP is thus a potentially useful tool for action at this level.

1.4 The HEADLAMP process

HEADLAMP has been developed as a practical methodology to address the adverse effects of specific environmental conditions on human health at the local level. Application of the HEADLAMP process follows three stages, as follows (see Figure 1.1):

1. *Definition of the problem.* The issue(s) to be addressed may be defined initially in many different ways: for example, through the concerns of the local community, as a result of local investigations, or as a consequence of priorities set at a wider level (e.g. as a local response to a National Environmental Health Action Plan). In each case, however, an essential prerequisite is a set of known links (validated by previous research) between a defined environmental factor and its associated health outcomes. Basic information needed to address this issue is identified at this stage. The participation of all relevant stakeholders concerned is also necessary, because the process is intersectoral, and aims to draw together not only the health agencies but also other sectors related to the problems at hand. Together, these various stakeholders can help to redefine the issue in clearer terms and to provide practical guidance and help in developing an appropriate methodology and locating relevant data.
2. *Compilation, assessment and quantification of relevant environmental health indicators.* During this stage, detailed data requirements are specified, taking account of the specific setting in which the analysis is being conducted, and the limitations of data availability. These data are obtained as far as possible from available routine data sources, but may be supplemented where necessary through the implementation of purposely designed, rapid surveys. Once collected, these data are then processed and analysed to provide information on the environmental health issues of concern. The variables produced through this process comprise the environmental health indicators. Depending on the problem and/or feasibility of obtaining all the relevant data, environmental health indicators may be derived either from health data (e.g. specific morbidity rates attributable to definable environmental factors) or environmental data (e.g. pollution levels with known human health implications). Where appropriate, these indicators are then linked (usually at an aggregate level) to provide further information on the environmental health situation.
3. *Formulation and implementation of appropriate policies.* At this stage, the trends and patterns shown by the environmental health indicators are interpreted and, based on this interpretation, appropriate

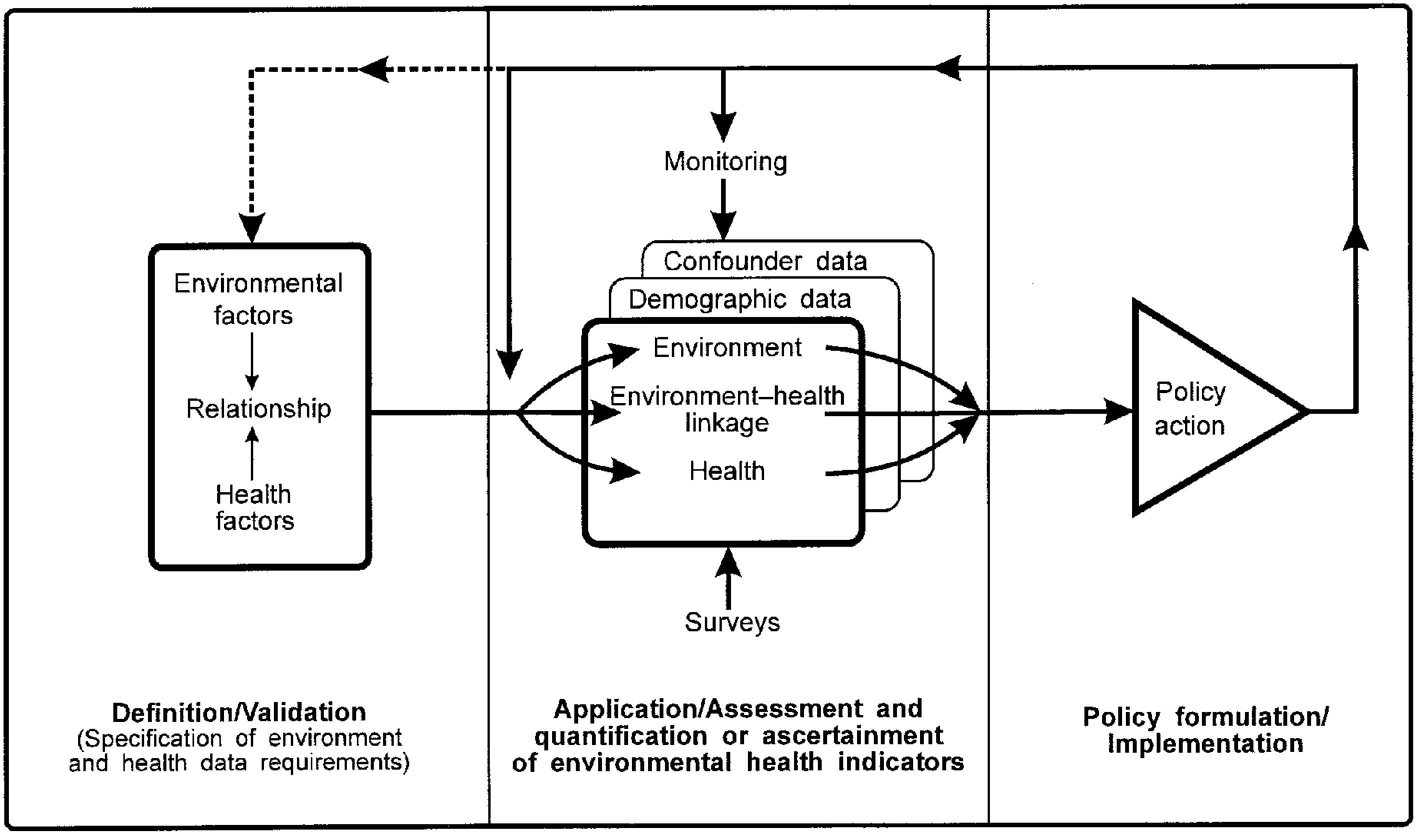

Figure 1.1 The HEADLAMP process

policy responses are defined, the relevant stakeholders and actors are informed, and the actions implemented.

In this context, the HEADLAMP process needs to be seen, not as a one-off activity, but as part of a continuing cycle of monitoring and policy review in which repeated assessments of health and environmental status are used first to develop, and then to revise, effective actions to reduce exposures likely to have adverse health effects. Thus, repeated assessments may be undertaken at appropriate intervals in order to monitor changes in health and/or environmental status and to detect any trends or patterns which may exist. These assessments also allow the effects of policy implementation to be monitored and can help to define any changes which might be needed. They also provide a source of environmental health information for the public and other stakeholders. Where appropriate, a decision to cease monitoring activities might also be taken once pre-set targets have been met on a sustained basis.

1.5 Summary

Application of the HEADLAMP approach is aimed at improving protection against environmentally related disease and the promotion of a healthy environment. Reduction of exposure requires investment by people and authorities. Given the shortage of resources for essential development activities in virtually all countries, scientifically sound and convincing information is essential to motivate and justify such investment. The information required is likely to include clear specification of the problem, its importance, and the costs and benefits of possible responses. Providing this information requires the availability of suitable methods of data analysis and linkage, as well as of indicators which can express the results of these analyses in terms which are understandable and relevant to decision-makers. Methods of data linkage and use of environmental health indicators can, therefore, be invaluable tools for policy-making and management.

The implementation of HEADLAMP activities at the local level should complement and support existing environmental health efforts. If effective decision-making and actions can be sustained and multiplied in many local situations, a significant impact at the national and global levels is expected.

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Chapter 2*

REQUIREMENTS FOR SUCCESSFUL ENVIRONMENTAL HEALTH DECISION-MAKING

2.1 The essence of environmental health decision-making

Environmental health programmes aim at preventing needless morbidity and mortality by protecting people from unnecessary exposure to environmental hazards. Unfortunately, despite the increasing knowledge about potentially harmful exposures, preventative action is often slow to follow. The mismatch between knowledge and application or translation is often most acute in developing countries, where environmental and occupational exposures often exceed national and international guideline levels, yet where corrective action to control these problems is limited. To reduce this growing deficit of action, research findings and monitoring data need to be translated more effectively and efficiently into public health practice. This requires the provision of the right type of information, and its communication to decision-makers in an easily understandable and appropriate form. Better tools to help decision-makers use the available epidemiological data also need to be developed. It has been argued that decisions are hardly ever taken because of evidence, but instead that evidence is usually used to support existing positions and policies (Hunt, 1993). Under this paradigm, individual decision-makers have been able to dictate actions on the basis of what is seen as politically favourable rather than responding to society's concern. Increasingly, however, ideals such as equity in health, environmentally sustainable development, public accountability and liability, and the formation of partnerships and involvement of the community and other important groups are changing this paradigm.

Decision-making is, certainly, a complex process. It involves choosing among alternative ways of meeting objectives. Implicit in this definition is the notion that there are a number of alternatives, and that their effects can be measured or estimated and compared (Warner *et al.*, 1984). This, in turn, implies that there is adequate information on which to make an informed choice. Often, however, these ideals are not met. Commonly, there is limited

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or inadequate information on the potential impact or costs of various policy alternatives, or even on what policy options are available. There may be confusion between the risks and benefits of specific interventions; for example reducing water chlorination to reduce the risk of cancer may increase the risk of waterborne diseases (Graham and Wiener, 1995). Those who gain and those who lose from the various actions may also differ, so that social values and scales have to be introduced to allow the options to be traded off against each other, and a decision reached. Together, this uncertainty and conflict may produce diverse conclusions about the "best alternative" when viewed by different observers.

The amount and type of information available is a major driving force for policy. The importance of information for decision-making is discussed in more detail in the following sections.

2.2 Historical development of environmental health decision-making

The links between the environment and public health have been known or at least suspected for many centuries. During the reign of Edward I of England (1272–1307), for example, it was recognised that the burning of "sea coal" produced "*so powerful and unbearable a stench that, as it spreads throughout the neighbourhood, the air is polluted over a wide area*" and this was found to be "*to the detriment of their [the citizen's] bodily health*" and therefore forbidden by direct order of the King (Wilson and Spengler, 1996). History has also shown that not all decisions taken are rapidly implemented. In this case the problem did not end with the signing of the King's orders. In the following reign, Edward II (1307–27) ordered air polluters to be tortured; half a century later, Richard II (1377–99) opted for the restriction of coal use through taxation (Wilson and Spengler, 1996).

This example is one case showing that concentration of efforts on the causes of ill health (health determinants) rather than on the health effects makes good sense. It also shows that the different decisions do not always lead to successful implementation of preventative measures. In many other situations the benefits of focusing on causes rather than effects has been less clear, in part because the links between some determinants and public health are not always direct. The effect of poverty on health status provides a classic example (WHO, 1996). In fact, the first systematic and convincing assessment of the efficacy of determinant-based interventions was probably that by McKeown (1976). This not only questioned the role of medicine in the improvement of health, but also presented evidence that the decline of mortality and morbidity in the past century was due primarily to limitation of family size, improvement of nutrition, a healthier physical environment (e.g. hygiene) and specific preventative measures, rather than a result of therapeutic action. From these observations McKeown (1976) and others infer that successful public health interventions are those which concentrate efforts on improving human environments, both physical and social, and claim that this is best achieved through the combined efforts of society at large, and not by the health sector on its own (Brown *et al.*, 1992). Although not without challenge (Sundin, 1990), the analyses of McKeown (1976) stimulated a revived interest in public health and preventative medicine, and a shift away from the therapeutic view which tended to dominate health policy in previous decades (Ashton, 1992).

The shift in focus towards an environmental perspective of health was echoed and endorsed by government reports and global health policy. In Canada in the mid-seventies, for example, an important report on the health of the population, known as the *Lalonde Report*, argued that future improvements in health status would be due mainly to improvements in the environment, lifestyles, and the increasing knowledge of human biology (Lalonde, 1974). This approach to health policy also allowed the active involvement of other disciplines and sectors in the health arena (O'Neill, 1993). In 1978, a similar change in thinking at the global policy level was witnessed. In that year, the first International Conference on Primary Health Care held in Alma Ata (former USSR) launched a major public health movement, known as "Health for All", which emphasised equity in health, health promotion and protection, intersectoral action, community participation and primary health care (WHO, 1978). The "Health for All Strategy" has been a major force for global action on health since then.

The links between development, environment and public health have taken global prominence over the past decade, particularly since the emergence of "sustainable development" as a guiding principle for policy, and the adoption in 1992 of Agenda 21 (United Nations, 1993) at the United Nations Conference on Environment and Development (UNCED). This has also helped to focus policy attention on environmental health determinants, particularly with respect to the impact of pollution and resource depletion.

The interactions between development, environment and health have been discussed in different contexts (e.g. Bradley, 1994; Warford, 1995). The links between these different areas is both varied and complex. In the context of tropical development, for example, Bradley (1994) cites twelve possible interactions where the activities of one area may favour or impede the functioning of each of the other two. So-called "win-win" situations would occur when both actions aimed at improving the environment or development also favour health. Examples are the improvement of water quality, in the first case, and reduction of poverty in the second. In turn, initiatives to improve health may favour both the environment and development.

Sustainable development has been defined as "*development that meets the needs of the present without compromising the ability of future generations to* *meet their own needs*" (World Commission on Environment and Development, 1987). Developments which jeopardise human health, whether through pollution or resource depletion, are clearly not sustainable. Principle 1 of the Rio Declaration, for example, clearly stated the case by placing human beings "*at the centre of concerns for sustainable development*" (United Nations, 1993). Chapter 6 of Agenda 21 takes this principle further by emphasising the fundamental commitment within sustainable development of "*protecting and promoting human health*".

It is widely accepted that until now, science and technology have been able to compensate for the world's unsustainable practices. Improvements in prospecting and production and the development of substitutes have generally masked the loss of environmental resources which has been taking place. Reliance on scientific research and technological improvements, however, disregards the risk that human pressures will ultimately outgrow the rate of "response" that science and technology can provide (McMichael, 1993). Adherence to the principles of sustainable development implies that tomorrow's science can no longer be relied upon to solve problems created today. Sustainable development implies both environmental and human health protection.

Viewed in these terms, it is clear that sustainable development is a narrow and fragile entity. If resources are not used efficiently and effectively, development may suffer and many in the world will be forced to remain at an unnecessarily low standard of living. Health, if not the environment, will certainly be impaired. On the other hand, even a slight excess rate of resource use, if continued for long periods, will deplete the world's resources and damage the environment, again to the detriment of human health. Sustainable development thus requires delicate guiding of human action, and well-targeted and well-informed policy. Information is therefore essential to agree the goals, to guide actions, and to assess progress in the desired direction.

2.3 Examples of successful environmental health decision-making

Taking decisions in general, and decision-making on environmental health in particular, is a complex process, involving people at all levels of society. This can be illustrated by the following example.

A government introduces a law regarding the use of seat-belts in cars. This law is motivated by statistics on severe injuries and deaths following motor vehicle accidents. Improved curative services are not an option. Knowledge of the determinants for several traffic injuries suggests a protective effect of seat belt use, and other preventative measures, such as the introduction of speed limits, installation of traffic signs and lights, and surveillance, among others. In collaboration with other sectors (such as the ministries of transport, justice and finance), a joint campaign is started for implementation of this law. Car manufacturers must be involved, for example in the development and installation of more comfortable and easier to use devices, and the public must be educated and encouraged (through mass media campaigns) to make use of them. In such a way, all relevant actors are involved in the process leading to and following the decision. In such an approach the probability that people will comply with the preferred decision of protecting car passengers by the correct use of seat-belts is maximised. In a parallel effort, the campaigns may be directed towards improving and promoting the use of public transport, and the use of other transportation means.

This example already suggests some core elements for successful implementation of decisions in environmental health policy, namely:

- The need for information (evidence).
- A focus on determinants rather than on health outcomes.
- The collaboration of different sectors involved in the particular problem.
- The involvement of all relevant stakeholders in society.
- The creation of a supportive environment.

Of these, the need for solid information, relevant and available to all parties, is fundamental. This relates to information on the problem itself as well as information to evaluate the proposed interventions aimed at addressing the problem. In addition, this information must be used in a joint effort of actors in all sectors relevant to the problem concerned. This includes the involvement of those who eventually will receive the health benefits of the decision, namely the community.

In order to elaborate on these core requirements, it is useful to consider a series of real-world examples, from different social and environmental contexts, and reflecting different approaches applied with different degrees of success. These include examples of actions (not necessarily decisions as such) which have improved people's environment, health and their lives as a whole. Of most interest, perhaps, are examples at the local level, because it is at this level that partnerships with, and involvement of, communities can be strongest, and where people can contribute, even on an individual level, to the decisions that affect them.

The first examples show the importance of creating supportive environments by the empowerment of people. Women and children in particular are often relatively disadvantaged in many developing countries, both in rural and urban areas.

- *Example 1. Empowerment of women in a farming area in Zambia.* In a rural area in Zambia the main crop produced was maize, the income from the sale of which was usually kept by men, with little benefit for the women and children, although they contributed considerably to its production. An intersectoral project of several government agencies and womens groups was implemented, which encouraged women to grow vegetables for sale and home consumption. A rural banking service for women was also introduced in the area. The result was the empowerment of women who were enabled to use their own skills for the family's benefit, ensuring a better food supply and thereby improving the nutritional status of their children (Haglund *et al.*, 1996).

- *Example 2. The rights of women in Belo-Horizonte, Brazil.* Profavela is the common term used for a law that recognises the rights of squatter settlements. Its enactment was due in great part to the strength of local community organisations. New legislation introduced in Belo-Horizonte paid special attention to the rights and needs of women. Women were recognised as the cohesive force that keep families together in low income settlements, and since few couples are officially married, property title deeds are preferentially given to women (United Nations, 1996a).

In the following example, empowerment of an ethnic/social minority group provided by government actions created a mutually beneficial situation.

- *Example 3. Waste management in Cairo.* In some cities in developing countries, up to 50 per cent of all the rubbish generated is not collected, but is left to accumulate in the streets where it poses a health hazard. In Cairo, the Zabbaleen people have followed a centuries old tradition of collecting and sorting rubbish found in the city streets. Recently, authorities have turned what was previously a tolerated activity into one which is positively encouraged. This decision proved to be mutually beneficial: the city's waste disposal system has improved and the status and living standards of the Zabbaleen was enhanced. Some 50 recycling and manufacturing businesses have been developed, with non-governmental organisations (NGOs) helping through the provision of basic equipment, training and seed funding (Buckley, 1996).

As the next example shows, having a clear vision of the local environment in which people live, work and recreate, is essential in order to mobilise people to take control of their environment and health. This helps promote community involvement and participation of all those concerned, and collaboration between all sectors which have a role to play in the health of people.

- *Example 4. The importance of a "vision".* Kuching prides itself on being a "Healthy City" and is recognised as the cleanest and most beautiful in Malaysia. This achievement has, to a large extent, come as a result of pursuing a clear and agreed vision. The city's dream is "*a well-planned, vibrant, landscaped garden city, endowed with a rich artistic, scientific and educational culture. A bustling city with a flourishing and resilient industrial economy, yet clean and unpolluted. A safe city, offering a* *standard of living affordable by all its citizens. A city managed efficiently and enjoying state-of-the-art communication, information and mass transport technology and providing ready access to services, utilities and recreation areas. A city that is dynamic and attentive to its people's needs and constitutional rights*" (Buckley, 1996).

The importance of having this sort of vision as a guide to action and as a goal for efforts was emphasised in the Habitat II workshop on "Best Practices in Improving the Living Environment", organised by the United Nations in Dubai in 1996 (United Nations, 1996a). As this workshop also showed, however, a vision alone is not sufficient; it cannot be a substitute for decisions and action. The next example shows that the political will to implement the community's vision must also exist.

- *Example 5. Community mobilisation.* From being renowned as the worst polluted city in the USA in 1969, Chattanooga came to be recognised as one of the nation's best success stories. What went right? An initial success in improving air pollution helped to mobilise the community behind a vision to become an "Environmental City". Collaboration between the government, industry and the community generated the required political will, funding and participation to develop strategies to solve existing problems, including housing, transport, recycling and neighbourhood revitalisation. The city has since been called a "living laboratory" for sustainable development (United Nations, 1996b).

Partnerships between the government, communities, the business sector and other important stakeholders are also crucial in laying the foundations for collaboration and success.

- *Example 6. Creating partnerships for action.* Rapid urbanisation in Dar es Salam has caused deterioration of environmental conditions. Environmental hazards include, among others, uncollected solid waste, incomplete incineration of refuse, poorly managed dump sites, and an increased number of unplanned settlements. In 1992 a consultation was held in the city with the purpose of establishing procedures and setting priorities in relation to the "Sustainable Cities" programme of the United Nations Centre for Human Settlements (Habitat). The consultation (with participation of persons from the community, private and government organisations) served to clarify priority urban issues, to establish intersectoral working groups and to establish a multidisciplinary technical support unit. As a result of this work the municipal government, in collaboration with the public and private sectors, began to work on the priority issues identified, with an explicit emphasis on sustainable urban development. The approach has succeeded in widening the basis for participation in the decision-making process and in mobilising a wealth of local resources through partnerships (Bartone *et al.*, 1994; United Nations, 1996a).

- *Example 7. Establishing partnerships and working groups.* Leicester was designated as the UK's first "Environment City" in 1990 because of its record for good environmental practice. Part of the success has been due to an approach based on integrated actions rather than looking at single issues. In addition, the need to identify solutions was stressed rather than just identifying the problems. The approach was to look for partnership rather than confrontation. Local promotional campaigns keep community members involved on a continuous basis. Several working groups were formed bringing together representatives of the community, decision-makers, experts and representatives of the business community, to look at specific areas such as transport, energy and the social environment (United Nations, 1996a; Darlow and Newby, 1997).

This process seems simple and direct. However, partnerships are not without problems. Participation of stakeholders is limited and self-selected. Some partners may feel intimidated in the setting of an "expert group" and will not participate (e.g. community members). Experts may also become frustrated and stop attending if the group disregards what these experts perceive as relevant and important (Darlow and Newby, 1997). Often, there are social and institutional barriers which impede the participation of individuals and community groups (Lawrence, 1996). Evidence, based on solid data and demonstrated to decision-makers is vital to the process of policy and decision-making, as illustrated in the following example.

- *Example 8. Demonstrating the evidence to decision-makers.* In 1990, Sweden introduced a law to limit blood alcohol concentration to 0.2 g l^{-1} for driving a motor vehicle. The new limit was introduced after demonstrating to decision-makers that, despite the popular belief that two beers were sufficient to exceed the 0.5 g l^{-1} limit, a person could drink enough alcohol to feel its effect (a drink before dinner, half a bottle of wine with a meal and a brandy afterwards) but still be under the limit and, thus, be legally able to drive under the influence of alcohol (Haglund *et al.*, 1996).

Focusing on the determinants of health requires long term planning and commitment, and needs strong political will. It has been argued that politicians are more concerned about immediate problems with short term goals (Hunt, 1993), but there are many examples of well-planned long-term projects.

- *Example 9. Public transport in a developing country city.* Curitiba is a city in Brazil which is known for its good "city management". One example is an innovative programme for public transport. Curitiba has more cars per capita than any other city, except for Brasilia, yet it has very few traffic jams. The reason is that 75 per cent of commuters use its public transport system. This was achieved by the introduction of special "busways" and specially designed bus terminals to allow for easy transfer to other routes. One single fare is paid for all journeys within the city limits. In summary, the public transport system is fast, efficient and affordable (Buckey, 1996).

Community commitment is an essential ingredient for success. Even torture for polluters seem to have failed Edward II of England in the example presented at the beginning of this chapter (at least, as evidenced by the fact that his successors had to continue dealing with the problem). More recently, lack of community commitment was one of the reasons for a failed air pollution control mechanism set up in Mexico City.

- *Example 10. Regulation without community commitment.* Mexico City is one of the largest and most (air) polluted cities in the world. Critical air pollutants are ozone, lead, carbon monoxide and fine particulate matter. By 1991, studies had indicated that fine particulates could be causing 12,500 extra deaths and 11.2 million lost days of work per year due to respiratory illness. Ozone was estimated to be responsible for 9.6 million lost work days per year, also due to respiratory illness. Excessive lead exposure was estimated to affect the development of about 140,000 children and cause hypertension in 46,000 adults. Total economic damages were conservatively estimated at US$ 1,500 million per year. An emergency air pollution control programme launched earlier, in 1989, had adopted tight motor vehicle emission standards, vehicle inspections and a rotating one day per week driving ban. However, this regulative approach lacked community commitment and failed. Many drivers bought a second car which, in many cases, was older. The regulation therefore increased the cost of its administration and air pollution (Bartone *et al.*, 1994).

Political boundaries often make control difficult. Transboundary air pollution (between countries) is a well known and documented problem (WHO, 1992). Boundary conflicts may also be a problem in pollution control at the local level.

- *Example 11. Overcoming government boundary conflicts.* Air pollution control in Mexico City is made more difficult because the problem is regional in scope. Air pollution originates in, and affects, the entire Valley of Mexico. Many federal, state and municipal agencies have a say in policy-making, and common actions by different jurisdictional areas (e.g. the implementation of preventative measures) are not easily achieved. To help solve these conflicts, the government created a commission for the prevention and control of environmental pollution in the metropolitan area of the Valley of Mexico, with the role of setting up prevention and control strategies for all aspects of environmental pollution, including air. This committee is now able to define and co-ordinate policies at all levels of government (Bartone *et al.*, 1994).

These case studies illustrate, with differing degrees of difficulty and success, some of the new ways of acting together at the local level. This approach includes efforts to enable and empower local authorities, to improve and use the local "knowledge base", and to build on and encourage the commitment of local people (United Nations, 1996a). The knowledge base is a crucial element — without it, local actions are likely to be poorly informed and inappropriate and, in many cases, will lack the commitment and conviction of the people they are meant to serve. The work described in the following sections and chapters thus concentrates on the question of how to develop and use this local information for decision-making in environmental health.

2.4 Difficulties and uncertainties in the decision-making process

The decision-making process is far from simple, and one in which numerous conflicts and uncertainties arise. One of the basic conflicts derives from the inexact nature of the process: while the public and politicians tend to expect rapid and clear-cut solutions, many problems are often complex and poorly understood, and the scientific evidence is conflicting (Neutra and Trichopoulos, 1993). As Steensberg (1989) stated, there is no definable boundary between what is safe or hazardous, but rather a zone of uncertainty. In many cases, therefore, it is only possible to talk in terms of the probability of an effect being produced. Given the limited public understanding of statistical probabilities and the concepts of risk, such language is not always appropriate or readily accepted (Jardine and Hrudey, 1998).

Decision-making is also bounded by a number of other constraints. Amongst these are problems of data availability and quality, and problems with the analysis and application of findings aimed at determining potential health impacts. Other constraints include uncertainties due to gaps, inconsistencies and errors in many of the data used; inadequate control for all possible confounders; poor quantification of the extent to which prevention can be achieved; extrapolating from evidence derived at high doses to determine risk at lower doses; extrapolating from data derived from animal evidence to determine human risk; extrapolating from past or current data to future health impacts; the need to allow for variations in individual susceptibility; the effects of combinations of exposures and multiple routes of exposure; the unreliability of many of the models used, and the difficulties of model verification; difficulties in defining and valuing intangibles such as quality of life.

Setting clear guidelines to facilitate the decision-making process is therefore not a simple endeavour. All these issues are subject to interpretation, and even experts are likely to disagree regarding both the weight to allocate to each and the conclusions to which they point.

Most decisions involve, and impinge on, a wide range of stakeholders and actors (Whitehead, 1993; Briggs *et al.*, 1998). These typically include scientists, who may be involved in the initial research which identified the problem, and in helping to devise solutions; business and industry, which may be implicated in the cause of the problem and may be partly responsible for implementing and financing solutions; planners, who may be involved in translating general policies into local action, and in monitoring implementation; the media, which may be involved in raising awareness about the problem and act as an unofficial watchdog on the actions taken; politicians, who are charged with making the decisions; and the public, who in the end must accept, pay for and live with the results of the decisions made. Each of these groups is likely to have different agendas. Each will also be moulded by a wide range of economic, professional, political and bureaucratic pressures. Consensus about the levels of risk involved, or about the relative merits of different policy actions, is therefore difficult to achieve (McMichael, 1991).

The need to involve the various actors and stakeholders at all stages in the decision process should not be treated lightly. Some questions, for example, are unanswerable in strictly scientific terms because of gaps in our knowledge. In these cases, a dialogue with the community is essential in order to reach a mutually agreeable solution. Science can provide guidance but not provide all the answers. An open and participatory approach is more likely to make the results more credible and acceptable, to provide time for the community to consider in advance the technical concepts and limitations and range of outcomes, and thus to allow decisions to be taken and implemented more effectively and speedily (Ozinoff and Boden, 1987). It is recognised, however, that the political process must support a participatory approach. In certain societies, civic organisations have remained weak, not formally recognised, repressive or non-existent. In such cases, an open participatory process is unlikely to be undertaken satisfactorily.

In this context, de Koning (1987) noted five characteristics of an effective standard-setting process which can be applied generally to decision-making in the area of environmental health:

- Involve the major parties in the community, including politicians, citizen groups, industrial leaders and health officials. This should stimulate debate encompassing differing perspectives and values, leading to some compromises being made in both goals and methods, thus ensuring broad support in the society at large.

- Provide a mechanism through which technical and policy analysis can be generated, distributed and criticised.
- Provide a mechanism whereby the results of analyses can be presented to policy-makers and the other centres of interest in the society, to inform these groups of the costs, benefits, and impact of the proposals under consideration.
- Provide a mechanism for conflicting interests to be heard and discussed in a controlled manner, so that divergent opinions in the society can be aired and, as far as possible, accommodated in the implementation of the proposal.
- Provide a mechanism whereby the society can reach a decision and take useful action, even though such action may be less than what is objectively ideal.

2.5 Conclusions

Decision-making requires the availability of better information and knowledge on the links between environment and health, but epidemiological research results are seldom definitive or conclusive (Omenn, 1993). However, it is inadviseable to delay while this information and knowledge is gathered, because while waiting for the information the problem continues and those affected have a right to know and to be protected (Sandman, 1991). It is necessary to be prepared, therefore, to act with the data and methods available.

Other chapters describe methods and tools to aid the decision-making process. The purpose of these is to help extract more information, more quickly, out of the data that already exist — and where adequate data are not available, to collect them speedily. The aim is to improve the utility of the information gained by providing results in a form directly usable by the decision-maker. As part of this purpose, the clear need is to encourage epidemiologists and other scientists to work more closely with decision-makers and each other, and for all three groups to interact more openly with the public and other stakeholders concerned.

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Chapter 3*

THE NEED FOR INFORMATION: ENVIRONMENTAL HEALTH INDICATORS

3.1 Introduction

It has been recognised that in many parts of the developing world the burden of disease attributed to environmental factors is large (WHO, 1997). Even in the developed world (and focusing for simplicity on the physical environment) new pollutants are emerging which pose threats to human health, and for which the health burden estimates are unknown or hard to measure. Against this background, there is clearly an urgent need for action to reduce the environmental health burden. This can be achieved, for example, through:

- Technological innovation to develop new, cleaner and more sustainable methods of production.
- Demand control to reduce the pressures from consumption and resource use.
- Environmental improvement to reduce the hazards involved, especially in those areas where human exposure may occur.
- Education and awareness raising to help individuals better appreciate the environmental risks to which they are exposed, and the personal opportunities which exist for risk avoidance and reduction.
- Therapeutic interventions to minimise the health impact on those already affected.

For any given environmental health problem, actions need to be taken through all the measures specified above. Certainly, technological innovations are likely to have a sustained, longer-term impact, but in the short-term public education and even therapeutic actions are also needed. All of these actions are potentially costly and therefore they all depend on the availability of reliable information. Information may thus be needed for the following (Briggs, 1995):

- To help identify and prioritise the problems which exist.
- To inform the numerous groups of stakeholders involved.
- To provide a rational framework for discussion and debate.
- To define, evaluate and compare the actions which might be taken.

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- To monitor the effects of these actions.
- To help specify safe limits and environmental guidelines and standards.
- To guide the research and development needed for the future.

The need for information to support policy and action in environmental health has been introduced in Chapter 2. This chapter focuses in more detail on the development of indicators suitable for decision-making. It takes on an epidemiological approach to understand the development–environment–health linkages and concentrates primarily on the technical aspects of obtaining usable and relevant environmental health information.

3.2 Indicators of development, environment and health

The term "indicator" is derived from the Latin *indicare*, meaning to announce or point out. Indicators represent more than the raw data on which they are based. They provide a means of giving the data added value by converting them into information of direct use to the decision-maker. Indicators are thus a crucial link in the data–decision-making chain: measurements produce raw data; data are aggregated and summarised to provide statistics; statistics are analysed and re-expressed in the form of indicators; and indicators are then fed into the decision-making process (Wills and Briggs, 1995). As such, an environmental health indicator can be seen as a measure which summarises, in easily understandable and relevant terms, some aspect of the relationship between the environment and health which is amenable to action. It is a way, in other words, of expressing scientific knowledge about the linkage between environment and health in a form which can help decision-makers to make better informed and more appropriate choices.

Environmental health indicators have the potential to contribute to improved environmental health management and policy. They are, however, of particular value in countries in which problems of access to natural resources remain, and in which issues of environmental pollution have traditionally taken second place to demands for economic development. Many of these countries are also confronted with hazards and diseases associated with poverty and lack of development (Environmental Research, 1993). In many countries problems of resource depletion, desertification and environmental pollution are rising. At the same time, populations are undergoing rapid expansion, particularly in urban centres, and these changes are in turn becoming an important driving force behind health and environment problems (Stephens, 1995; Harpham and Blue, 1997). In recent years, awareness has been growing of the association between economic growth and environmental protection (World Bank, 1992; United Nations, 1993) and, in many countries, strategies for sustainable development aimed at both preserving the environment and enhancing quality of life are being implemented (e.g.

Projecto Estado de la Nacion, 1995; Environmental Health Commission, 1997). If decision-makers are to take the actions needed to prevent irreversible and costly health and environmental damage, they urgently need reliable and relevant information on levels of environmental pollution and their links with human health.

The concept of indicators is far from new. The use of indicators has a long history, for example in economics (e.g. indicators such as Gross National Product (GNP) and the unemployment rate), resource management (e.g. indicators of land suitability) and ecology (e.g. the use of indicator species and of ecosystem health) (Rapport, 1992). In recent years, however, there has been a marked growth in interest in the use of indicators in many other fields. The use of social indicators (e.g. of deprivation, poverty) is now widely accepted (e.g. Jarman, 1983; Carstairs and Morris, 1989; UNDP, 1997), while performance indicators are being used increasingly to monitor the activities of industry and the public services. Indicators have also become well-established in the fields of both environment and health (e.g. UNEP, 1993; WHO, 1993a).

There are four main categories of indicators in use that are considered relevant in the context of development, environment and health. These are sustainable development indicators, environmental indicators, health indicators and environmental health indicators. While there are important overlaps among these, the focus of this chapter is on the indicators which can contribute usefully to environmental health policies.

3.2.1 Sustainable development indicators

One of the most important stimuli for indicator development in the areas of environment and health has been the emergence of sustainable development as a guiding principle for policy, and the adoption in 1992 of Agenda 21 at the United Nations Conference on Environment and Development (UNCED) (see Chapter 2). Countries and international governmental and non-governmental organisations (NGOs) were called upon to develop the concept of indicators of sustainable development. The Statistical Office of the United Nations was given a special role to support this work and to promote the increasing use of such indicators. National programmes for indicator development have thus been set up in many countries to support environmental policy and State of the Environment reporting (e.g. Environment Canada, 1991; Adriaanse, 1993). The adoption of Local Agenda 21 has similarly encouraged the establishment of sustainability indicators by local governments and city authorities (e.g. Gosselin *et al.*, 1993; Sustainable Seattle, 1993; Local Government Management Board, 1994). Internationally, several organisations have attempted to construct core sets of indicators to monitor global environmental trends (e.g. OECD, 1993, 1997; UNEP/RIVM, 1994; World Bank, 1994; World Resources Institute, 1995; Worldwide Fund for Nature and New Economics Foundation, 1994).

The United Nations has recently listed 130 sustainable development indicators to be tested in countries (United Nations, 1996). Many of these indicators, however, do not reflect the sustainability aspect they wish to measure. Economic performance indicators, such as GNP or the annual GNP increase, tell us nothing about the ability of future generations to sustain development. In fact, it could be speculated that a high GNP today may be the direct cause of a lowered GNP tomorrow, if natural resources are depleted and the high current GNP has been created at the expense of the community's future productivity. Although the concept of sustainable development has, to some extent, been adopted by politicians to refer to short-term economic goals, economic performance in itself is not the ultimate aim of sustainable development. Instead, long-term human health and welfare, biodiversity protection and global ecosystem health are the key objectives of sustainable development (Gouzee *et al.,* 1995). Most environmental indicators (e.g. air quality) or health indicators (e.g. life expectancy) provide no information about sustainability as such, but they are at least essential elements of community well-being. Some environment and health indicators can also be interpreted more directly in relation to sustainability. For example, an indicator of soil quality or soil stability could be interpreted as directly linked to future agricultural productivity and the ability of future generations to meet their needs. Similarly, a health indicator, such as the occurrence of infectious disease in a community, could be interpreted in relation to likely health problems in the future.

Attempts have also been made to assess other aspects of development, for example human development. An example of this is the human development index (UNDP, 1990). More recently, other measures of human development have been introduced, such as the human poverty index (UNDP, 1997).

3.2.2 Environmental indicators

Environmental indicators have been described as "*a measurement, statistic or value that provides a proximate gauge or evidence of the effects of environmental management programs or the state or condition of the environment*" (US EPA, 1994). In recent years, several programmes have been established to monitor the environment for health-related purposes, for example the Global Environment Monitoring System (GEMS) for air (UNEP/WHO, 1993; see also WHO, 1987), water (WHO, 1991) and food (WHO, 1990). Nevertheless, issues relating to health are just a few of the many reasons for collecting environmental indicators. Other reasons include the impact of environmental pollution on agriculture, forests, rivers and lakes. Thus, the collection of data on air pollution emissions and concentrations, organic and inorganic water pollution, stratospheric ozone, natural resources, waste production, climate change, etc., is not performed specifically for health related purposes. In the context of human health it is mostly the degree of exposure of humans to potential health risks that is of concern, and consequently the human health impact of contaminants (and other risk factors) in the environment.

The difficulty with environmental indicators is that the presence of pollutants in the environment does not translate automatically into health outcomes. Similarly, the incidence of many environmentally-related diseases cannot be easily traced back to specific environmental exposures. Only individual-level epidemiological studies are able to establish reliable links between exposures and health outcomes. Such studies, however, cannot on their own provide the information needed to support action and policy, and defeat the purpose of using easily collected or available statistics to derive, quickly and cost-effectively, environmental health indicators.

3.2.3 Health indicators

Health indicators have been used extensively to monitor the health of populations. The "Health for All" policy, for example, involves monitoring progress towards a minimum health level for all persons by the year 2000 and provides numerous examples of health indicators on a global scale. The information gained from monitoring is used for evaluation, i.e. the continuous follow-up of activities to ensure that they are proceeding according to plan, so that if anything goes wrong, immediate corrective measures can be taken (WHO, 1993a). The health–environment link is also a prominent part of the "Health for All" process. Important environmental health issues, such as access to water and sanitation, acute and chronic exposures to chemicals, population exposures to unacceptable levels of contaminated air, housing issues (as well as broader environmental issues with a less direct link to health, such as loss of biodiversity, deforestation, soil degradation and global warming) are all addressed in the publication *Implementation of the Global Strategy for Health for All by the Year 2000* (WHO, 1993b).

Health indicators are usually defined in terms of health outcomes of interest. The Swedish Environmental Protection Agency has compiled a tentative list of environment-related diseases (SEPA, 1993) which can be used for this purpose. This list includes certain cancers (especially lung and skin, particularly in children); respiratory disease (chronic bronchitis, pulmonary emphysema, bronchial asthma, hyper-reactivity); allergic diseases (atopic allergies and symptoms occurring in connection with atopic diseases, namely asthma, hay fever, conjuctival catarrh and eczema); cardiovascular diseases; effects on reproduction (miscarriage, late intrauterine death, neonatal and perinatal death, low birth weight, various malformations and chromosome abnormalities); and diseases of the nervous system (organic psychosyndromes and dementia (Alzheimer's disease), Parkinson's disease, amyotrophic lateral sclerosis, peripheral nervous disease in combination with polyneuropathy). Not all cases of these diseases are due to environmental exposures and not all environment-related diseases are included in this list. For example, certain infectious diseases would be prominent environment-related diseases in less developed countries. Nevertheless, these diseases do provide a means of monitoring and assessing the health outcome of a wide range of environmental exposures.

The term "public health surveillance" is used to describe the collection, analysis and interpretation of data on specific health events, for the purpose of prevention and control (Thacker *et al.*, 1996). Surveillance in environmental health extends this concept by including surveillance of hazards and exposures (Hertz-Picciotto, 1996; Thacker *et al.*, 1996). The term "sentinel health event" has been applied to cases of disease that, in a particular situation, appear out of the ordinary, and which can be potentially linked to an external factor, for example infant or maternal deaths as indicators of the adequacy or quality of prenatal or maternal health care. The concept of sentinel health events is especially appropriate in relation to occupational health, and currently more than 50 conditions are considered as occupational sentinel health events (e.g. asbestosis and mesotheliomas as indicators of asbestos exposure) (Mullan and Murthy, 1991). A preliminary list of environmentally-related sentinel health events has also been devised (Rothwell *et al.*, 1991). In practice, however, there are few diseases which can be used as sentinels of environmental exposures.

3.2.4 Environmental health indicators

Environmental health is concerned not with the health of the environment *per se*, but with the ways in which certain environmental factors can influence or directly affect human health (in either a positive or negative way). An environmental health indicator can thus be defined as:

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

Several aspects of this definition are worthy of emphasis. The first is that an environmental health indicator embodies a linkage between the environment and health. As such it is more than either an environmental indicator or a health indicator. Environmental indicators represent indicators which describe the environment without any explicit or direct implications for health. The vast majority of environmental indicators so far developed are of this type, for example indicators of atmospheric emissions, surface water quality, designated areas or threatened wildlife species. Health indicators are indicators which describe the status of, or trends in, health without any direct reference to the environment. Again, the majority of health indicators so far developed are of this type; examples include simple measures of life expectancy, or cause-specific mortality rates where no attempt has been made to estimate those health outcomes attributable to the environment.

Given knowledge of the relationship between specific environmental exposures and health effects, however, both environmental indicators and health indicators can be converted into environmental health indicators. An environmental health indicator is thus a measure which indicates the health outcome due to exposure to an environmental hazard. As such, it is based upon the application of a known or postulated environmental-exposure health–effect relationship. In this respect, two general types of environmental health indicators can be distinguished:

- An *exposure-based indicator* projects forward from some knowledge about an environmental hazard to give an estimated measure of risk. Such indicators can be conceived as the combination of an environmental indicator with a known environment–health relationship (e.g. the estimated health impact, such as respiratory disease, from known levels of air pollution).
- An *effect-based indicator* projects backwards from the health outcome to give an indication of the environmental cause (i.e. the environmentally attributable health outcome, such as the proportion of current diarrhoea death rates which can be attributed to poor water quality).

Within the context of environmental health, the word "environment" is understood to comprise all that which is external to the human host, including physical, biological and social aspects, any or all of which can influence the health status of populations (Last, 1995). The environment, therefore, encompasses not only the general environment to which everyone is exposed, but also specific environments, such as the workplace and the domestic environment, where people spend a significant proportion of their time. Further, one must also include among environmental health hazards not only the immediate biological, chemical or physical factors that affect health, but also the underlying social, economic and technical conditions that give rise to (and modify) environmental health problems. An indicator which purely describes the state of the environment with no obvious link to health impacts of the environment could not be considered an environmental health indicator. In the same vein, a pure health status indicator with no obvious linkage to environmental causation of health deterioration (or health improvement), could not be considered an environmental health indicator.

Figure 3.1 provides a graphic description of the relationship between the three related arenas of environment, health and environmental health. The

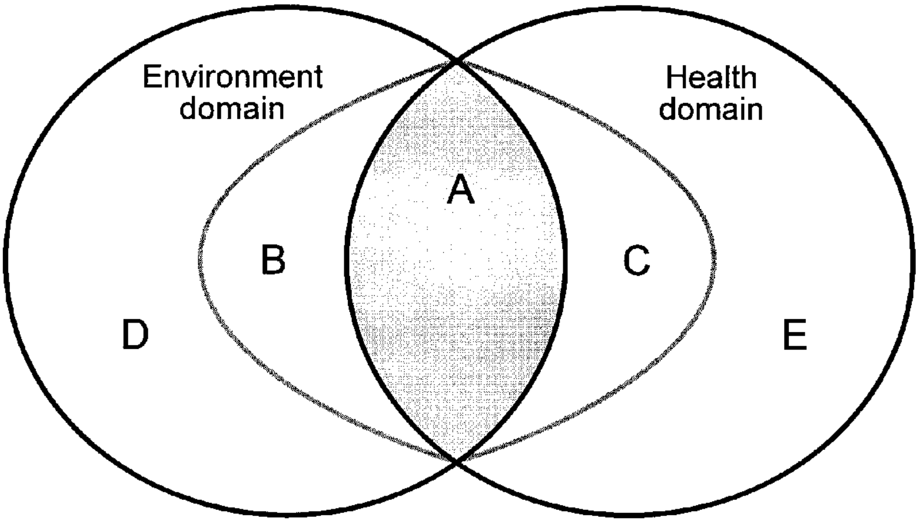

Figure 3.1 The scope of environmental health indicators. **A.** Environmental health indicators; **B.** Environmental indicators indicating potential human health impacts; **C.** Health indicators with unknown but possible environmental cause; **D.** Well defined environmental indicators; **E.** Well defined health indicators

area relating to environmental health indicators (area A) is formed by the area of intersection (or linkage) between the environment and health. This is the area in which known (or suspected) environmental factors are associated with known (or suspected) health outcomes; for example the effects of severe air pollution on respiratory disease in children, or of poor sanitation on gastrointestinal disease. Area B represents the area in which the environment, while not directly influencing human health, may nevertheless contribute more tenuously to health outcome. Examples of this include deforestation and desertification, which do not have a well-defined, direct or immediate linkage with health; or environmental exposures which we have not yet identified as hazardous to health. Area C represents health outcomes (e.g. diseases such as certain cancers) with unknown but possible environmental causes. Areas D and E represent those areas of environment and health, respectively, wholly outside the realm of environmental health, i.e. where there is no apparent link between environment and health. For the sake of simplicity, the schema presented in Figure 3.1 deliberately excludes factors, such as economic and social conditions, which may affect the environment and health (House *et al.*, 1988) but which may act as modifiers of the health effects resulting from the environment. Poverty, for example, may exacerbate the health effects of exposures to environmental pollution both by increasing susceptibility of the population (as a result, for example, of inadequate nutrition) and by reducing access to early health treatment (e.g. Ostro, 1994).

Indicators can be devised and constructed for each of the areas shown in Figure 3.1. Because reliable environmental health indicators can only be developed where the association between environment and health is clear and strong, the most useful indicators occur in area A. In areas B and C, the link between environment and health is either weaker or less certain. In these areas, therefore, reliable indicators are more difficult to define, and any environmental health indicator will need to be interpreted with particular care; it will rarely be possible to assume that changes in the indicator necessarily reflect the effect of environment on health. Areas D and E are the terrain of explicit and independent environmental indicators and health indicators. Indicators in this area cannot be considered legitimately to be measures of environmental health.

The areas shown in Figure 3.1, however, are not fixed. The boundaries between the various areas may change as our knowledge of the links between environment and health develop. As knowledge improves (e.g. as a result of advances in epidemiological research), therefore, so area A may expand to encompass progressively more of areas B and C. As new theories emerge about potential environment–health effects, so areas B and C may expand into D and E. Equally, new research may disprove assumed relationships, causing a contraction of the area occupied by environmental health. In the process, the meaning and utility of existing indicators may change, and opportunities may develop for the construction of new indicators, aimed at new concerns.

Another important characteristic of an environmental health indicator is its relationship with policy or management. Any environmental health indicator must be useful. To be useful, it must relate to aspects of environmental health which are both of relevance to the decision-maker and, directly or indirectly, amenable to control. Given that the collection of information invokes costs, and that these costs will need to be justified, it will rarely make sense to collect information or try to construct indicators which will not be used in support of policy. This means that most indicators are built around areas of existing policy; the policy imperative creates both the need for indicators and justifies the costs of constructing them. Some of the most valuable uses of indicators, however, are to help identify and assess new policy questions. This means that some indicators need to be developed in advance of a clear and definite policy need. A spectrum of environmental health indicators can thus be identified, reflecting the strengths of their links with policy. At one end are those indicators which have a clear and known use in relation to existing policy or recognised concerns. In the middle are those indicators which are based on less clear policy needs, but which over time may help to guide and direct new policy developments. Beyond, lie those indicators with no apparent policy relevance. Because of the economic considerations involved in indicator development, most attention tends to be devoted to the first of these three categories. However, the uncertainty of present knowledge about environmental health, the length of time it often takes to investigate new problems, and the long latency times which often exist between exposure and health effect, mean that risks are being taken if attention is not focused in this area. Thus, new problems are likely to occur unexpectedly. Consequently, the "precautionary principle" needs to prevail and indicators are needed that give an early warning of new environmental health effects in time to address them before they become severe. In the long term, it is therefore the more prospective indicators (i.e. those at the margins of existing policy) that are often the most important. Unfortunately, these are often the most difficult to justify.

A third aspect of this definition is that environmental health indicators must be expressed in a way which is pertinent to, and understandable by, the decision-makers concerned (Gosselin *et al.*, 1993). In many circumstances, this requires that the indicator be expressed in terms of the health risk associated with a specific environmental hazard, because this provides a universally recognisable "currency" by which to assess and compare different problems. Possibly the most meaningful measure is thus one that provides estimates of the severity and magnitude of the health outcome (e.g. the number of additional deaths, the number of additional hospital admissions, or the number of additional cases of morbidity). In practice, it is often difficult to calculate with any certainty the actual health effect in these terms, because these estimates rely upon having a quantitative understanding of the dose–response relationship. An alternative may be to express the indicator in terms of the number of people "at risk". This can often be estimated from knowledge of the levels of exposure across the population. Often, however, even this may be difficult (e.g. where pollution levels are measured at too few sites to allow estimates of the population exposure). In these situations, the indicator may be expressed simply in terms of environmental concentrations, or some measure of source activity. The further the indicator is removed from the health outcome, the less clearly it expresses the health risk involved, and the more uncertain any interpretations of these risks will be. On the other hand, because policy action, especially preventative action, is often targeted at the source of the pollution, these more remote, source-based indicators may still be very valuable in terms of guiding policy.

All these considerations have important implications for the way in which data is collected and the indicators concerned are constructed and presented. Some of the criteria which help to make good environmental indicators are therefore considered in the next section.

3.2.5 Criteria for indicator development

While indicators are intended to provide a simplification of reality, they are themselves far from simple. Unless this underlying complexity is understood, indicators may end up being developed in relatively fuzzy and ill-defined terms. Gosselin *et al.* (1993), for example, derived from an extended list, a set of 20 indicators for measuring and reporting progress of sustainability. Among these are indicators which are relatively self-explanatory both in terms of what they are meant to indicate and how they should be constructed and measured; for example energy consumption per capita or employment to population ratio. Others, however, are less clearly defined (e.g. public transport use compared with car or major water pollutant emissions); these would need to be further clarified before they were developed. As a result, it is not clear how the indicator should be measured, what data are needed, or how it can be interpreted. As this implies, clear definitions and explanations about every aspect of the indicator to be used are crucial. Poorly conceived or inadequate indicators are likely to be a waste of time and effort, and they are likely to misinform, rather than inform, the users.

It is all too easy, therefore, to propose indicators which do not, in reality, indicate anything — or at least not what the user assumes. Good indicators require careful planning and design. They depend upon an understanding of the questions being addressed, of the way in which they will be used, and of the way in which the systems involved operate. In addition, they need to be formulated and defined very precisely, and they often need to be tested before they can be used.

Fortunately, in recent years much has been learned about the development and use of indicators in a wide range of decision-making areas. On the basis of this experience, a number of criteria have now been established for general indicator selection and construction (e.g. Kreisel, 1984; UNEP/RIVM, 1994; OECD, 1997). These can be further adapted in relation to environmental health. Pastides (1995) takes an epidemiological approach to arrive at two fundamental criteria:

- That the indicator should reflect an underlying causal mechanism.
- That the indicator should be a valid estimate of the causal relationship.

If indicators are to be used to assist decision-making, however, they cannot be judged solely in terms of their scientific validity. Factors such as utility, acceptability and cost of construction also become important. For most purposes it is thus more useful to recognise two fundamental sets of criteria: those relating to their scientific validity and those relating to their relevance and utility. Box 3.1 lists some of the main criteria that can be identified under each of these headings. It is important to recognise that not all these criteria can necessarily be achieved in all circumstances. Problems of data availability, resources and the need for compatibility with previous indicator

Box 3.1 Criteria for environmental health 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 that 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.

series may mean that some have to be sacrificed. Nevertheless, the criteria listed in Box 3.1 provide a useful checklist against which to judge environmental health indicators, and in general good indicators are likely to satisfy most, if not all, of these criteria.

3.3 A conceptual framework for environmental health indicators

3.3.1 The environment–health chain

The link between environment and health operates through the exposure of humans to environmental hazards. These hazards may take many forms — some are wholly natural in origin whereas the majority derive from human activities and interventions. In all cases, however, health effects only arise if humans are exposed, often at a specific place and time, to the hazards which exist.

The environment–health pathway is most clearly seen in the case of exposure to pollution (Lioy, 1990; Sexton *et al.*, 1992, 1994; Pirkle *et al.*, 1995) (Figure 3.2). Most environmental pollutants are the product of human activities. These may be released into the environment in a variety of ways, and

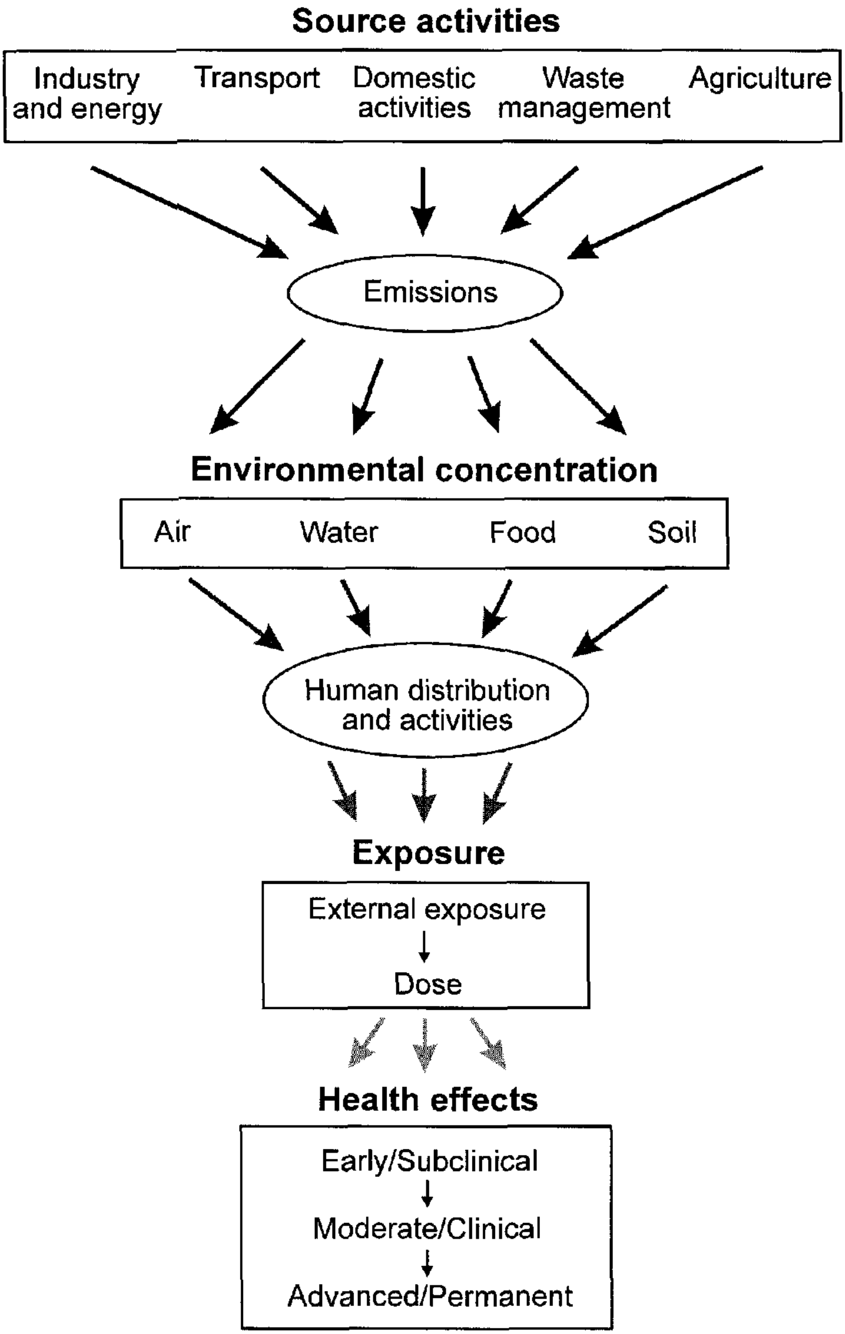

Figure 3.2 The environmental health hazard pathway. Arrows indicate the flow from source activities to health effects (e.g. pollutants). Arrow shading indicates the likely weakening of the impact from source activity to health effects.

may then be dispersed and accumulate in different environmental media (e.g. the air, water, soil, food). Exposure occurs when humans encounter the contaminants within any one of these media. A range of health effects may then occur, from minor sub-clinical effects through illness to death, depending upon the intrinsic harmfulness of the pollutant, the severity of exposure and the susceptibility of the individuals concerned. The whole process is often driven by persistent forces which motivate the creation of the hazard and increase the likelihood of exposure. Thus, population growth, economic development, technological change and (behind these) social organisation and policies may all lie at the root of the problem. Because of its potentially wider impact, it is often here where action needs to be addressed.

3.3.2 The DPSEEA framework

The environment–health chain illustrated by the example of pollution provides a useful organising framework for the development and use of environmental health indicators. However, to make it more generally applicable (e.g. to other forms of environmental hazards), and to set it more firmly within a decision-making context, it needs to be further conceptualised.

Over recent years, a number of attempts have been made to devise conceptual frameworks for indicator development. Of these, the one which has been most widely adopted has been the simple pressure–state–response (PSR) sequence, initially applied by the Organisation for Economic Co-operation and Development (OECD) as a framework for State of the Environment reporting (OECD, 1993, 1997). A slightly modified version is currently in use by the United Nations to develop sustainable development indicators (United Nations, 1996). In many ways, however, the PSR sequence has proved too limiting, and it has more recently been extended to include recognition of the "driving forces" responsible for pressures on the environment, and of the effects which often precede the policy response (e.g. US EPA, 1994). Figure 3.3 further adapts these concepts to provide a specific framework which addresses the driving forces, pressures, state, exposures, effects and actions (i.e. DPSEEA) for the development of environmental health indicators. This framework acts as a valuable guide to designing indicators in a wide range of situations; for example in developing indicators to address a specific environmental hazard (e.g. air pollution) or a specific health problem (e.g. respiratory illness in children), or to describe the whole web of links between environment and health which may occur in a specific area (e.g. a local community). It has also proved useful in describing and analysing the global situation in relation to health, environment and development in a recent report entitled *Health and Environment in Sustainable Development* (WHO, 1997).

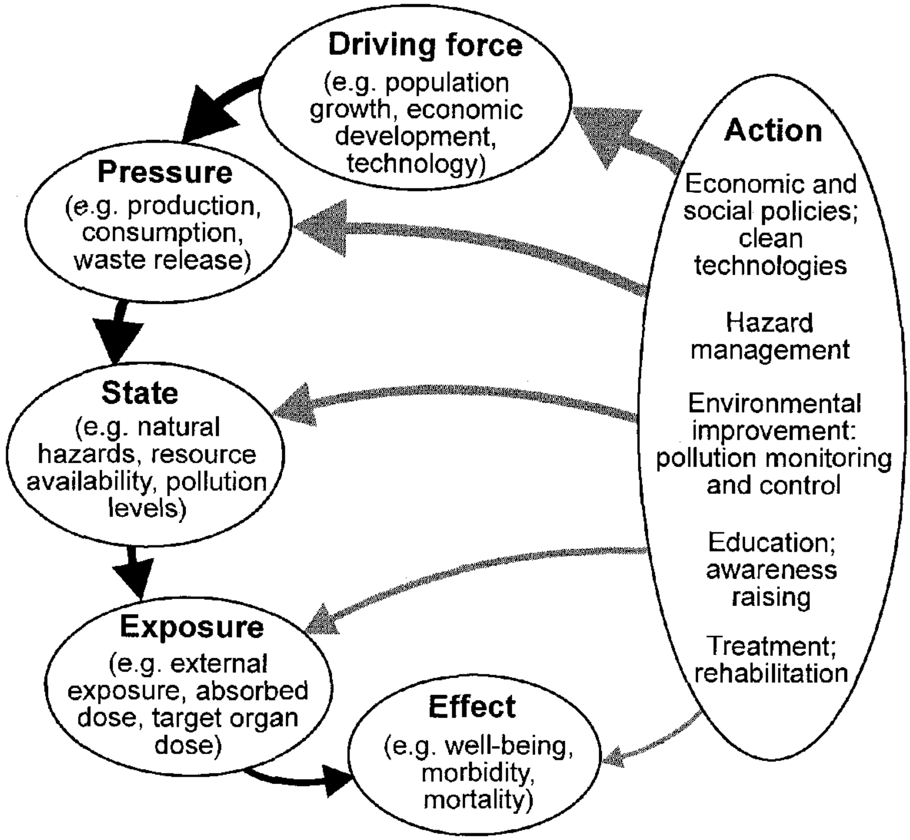

Figure 3.3 The DPSEEA framework (After Corvalán *et al.* 1999)

Driving forces
Within the DPSEEA framework, the driving forces component (D) refers to the factors which motivate and push the environmental processes involved. One of the most important of these is population growth (Canadian Journal of Public Health, 1991; Winkelstein, 1992; McMichael, 1993; Bongaarts, 1994). Almost inevitably, this results in more people being exposed to environmental hazards simply by virtue of the increased number of people living in the areas concerned. More indirectly, it tends to lead to the intensification of human activities within these areas, thereby contributing to environmental damage and resource depletion (Litsios, 1994). In some cases it also results in expansion of human populations into more marginal zones. Here, the inherent instability of the environment may mean that the population is especially vulnerable to environmental hazards, while the environment in turn is especially sensitive to damage. A wide range of other important driving

forces also exist, including technological development, economic development and policy intervention (e.g. see Warford, 1995).

Pressures

The driving forces within the DPSEEA model result in the generation of pressures (P) on the environment. These pressures are normally expressed through human occupation or exploitation of the environment. Pressures are thus generated by all sectors of economic activity, including energy production, manufacturing, transport, tourism, mining and agriculture. In each case, pressures arise at all stages in the supply chain — from initial resource extraction, through processing and distribution, to final consumption and waste release.

One of the most important components of these pressures in the context of human health is clearly the release of pollutants into the environment. These releases may occur in a wide variety of ways, and into different environmental media. Energy combustion, for example in vehicles, manufacturing industries, electricity generation and home heating, is one of the most important emission processes, especially to the air. Large quantities of pollutants are also emitted through other processes, such as spillage of chemicals, the deliberate discharge of effluents, dumping of wastes, leaching of agricultural chemicals, etc. Because these activities and processes represent the starting point for environmental emissions they also represent the most effective point of prevention and control. Once in the environment, pollutants may be widely dispersed and may undergo a wide range of secondary transfers. Environmental policy is therefore focused at trying to regulate source activities, or to incorporate in them methods of emission control.

State

In response to these pressures, the state of the environment (S) is often modified. The changes involved may be complex and far-reaching, affecting almost all aspects of the environment and all environmental media. Thus changes occur in the frequency or magnitude of natural hazards (e.g. in flood recurrence intervals or in rates of soil erosion); in the availability and quality of natural resources (e.g. soil fertility, biodiversity); and in levels of environmental pollution (e.g. air quality, water quality). These changes in the state of the environment also operate at markedly different geographic scales. Many changes are intense and localised, and are often concentrated close to the source of pressure (e.g. habitat loss, urban air pollution, contamination of local water supplies). Many others are more widespread, contributing to regional and global environmental change (e.g. desertification, marine pollution, climate change). Because of the complex interactions that characterise the environment, almost all these changes have far-reaching secondary effects.

Exposure

Environmental hazards, however, only pose risks to human well-being when humans are involved. Exposure (E_I) thus refers to the intersection between people and the hazards inherent in the environment. Exposure is rarely an automatic consequence of the existence of a hazard. It requires that people are present both at the place and at the time that the hazard occurs.

The concept of exposure is best developed in relation to pollution. The National Academy of Sciences (1991) defines exposure as: "*an event that occurs when there is contact at a boundary between a human and the environment with a contaminant of a specific concentration for an interval of time*". In the case of environmental pollution, therefore, exposure can occur in a number of different ways, i.e. by inhalation, ingestion or dermal absorption, and may involve a wide range of different organs. External exposure refers to the quantity of the pollutant at the interface between the recipient and the environment. The amount of any given pollutant that is absorbed is often termed the "absorbed dose", and may be dependent on the duration and intensity of the exposure. The "target organ dose" refers specifically to the amount that reaches the human organ where the relevant effects can occur (Sexton *et al.*, 1995). Exposure may be assessed in a range of different ways. External exposure is often measured using some form of personal monitor (e.g. passive sampling tubes for air pollution) or by modelling techniques (e.g. based upon knowledge of concentrations in the ambient environment). Biomarkers are indicators of exposure, dose, effect or susceptibility given by evidence found in biological samples (Links *et al.*, 1995). Sources of exposure data are discussed further in Chapter 5.

Historic data on pollution levels are often particularly sparse. Significant uncertainties in exposure classification consequently tend to occur, and the existence of a measurable concentration of a pollutant, even when higher than recommended levels, is not always a sufficient basis to infer health effects. Moreover, exposure often occurs to a number of different pollutants, in combination, and thus environmental concentrations of one pollutant do not always give a good indication of potential health effects. Social and other factors may also distort or mask the association between exposure and health outcome. Sexton *et al.* (1992) make several recommendations regarding the collection of data on human exposures. These include the need for standardised procedures for collection, storage, analysis and reporting; the involvement of different sectors for the design and maintenance of these databases; the collection of data at relevant levels of resolution (i.e. micro-environments where people are actually exposed); and the development of valid predictive models of exposure.

Effects

Exposure to environmental hazards, in turn, leads to a wide range of health effects (E_2). These may vary in type, intensity and magnitude depending upon the type of hazard to which people have been exposed, the level of exposure and the number of people involved. For convenience, a simple spectrum of effects can often be recognised. The earliest, and least intense, effects are sub-clinical, merely involving some reduction in function or some loss of well-being. More intense effects may take the form of illness or morbidity. Under the most extreme conditions, the result is death.

Health effect can be acute (e.g. microbiological contamination of water related to infant diarrhoea) or chronic (e.g. low levels of arsenic contamination in water related to cancer). Some contaminants may have a rapid effect following exposure, whereas others may require accumulation in the target organ before an adverse health effect can be observed. In such cases there may be a significant time lag (or latency period) between exposure and health effects. Health outcomes observed at present may be due to exposures which occurred many years or even decades earlier, as is the case with certain cancers, with consequent uncertainty regarding the actual dose the individual affected may have received (Rose, 1991).

One approach for assessing the impact of specific environmental exposures on health is quantitative risk assessment. Given known exposures and knowledge of dose–response functions, it is possible to make reasonable estimates of the health burden of specific pollutants. Further elaboration of risk analysis methods is needed, however, in order to provide a better basis for indicator development, by providing inexpensive and rapid estimates of the health impact of specific environmental exposures at the aggregate level (Nurminen and Corvalán, 1997).

Actions

In the face of environmental problems and observed health effects, society may attempt to adopt and implement a range of actions (A). These may take many forms and be targeted at different points within the environment–health chain. In the short term, actions are often primarily remedial (e.g. the treatment of affected individuals). In the longer term, actions may be protective (e.g. by trying to change individual behaviour and lifestyle to prevent exposure). Alternatively, actions may be taken to reduce or control the hazards concerned (e.g. by limiting emissions of pollutants or introducing measures of flood control). Perhaps the most effective long-term actions, however, are those that are preventative in approach, i.e. aimed at eliminating or reducing the forces which drive the system.

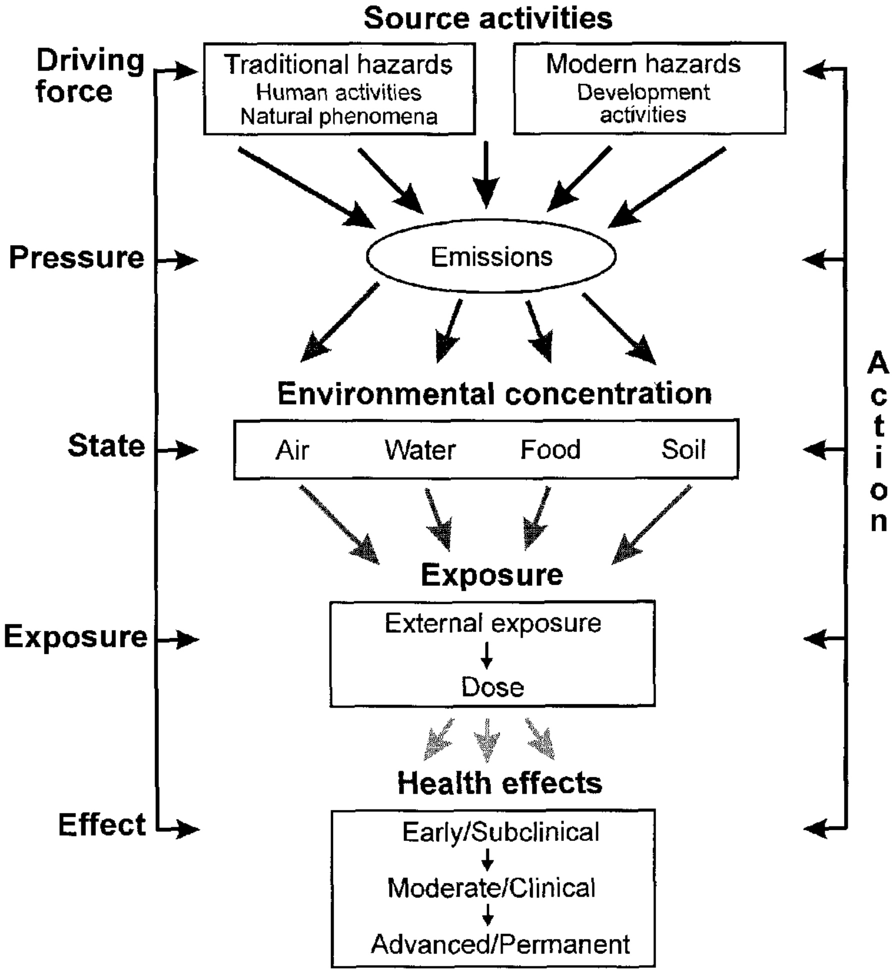

Figure 3.4 A simplified diagram of the environmental health hazard pathway and its link with the DPSEEA framework

3.4 Using the DPSEEA framework

In many situations, the causal pathway which has been described above can be quite complex; rather than a simple chain, it acts as a network of connections (Figure 3.4). For example, multiple effects may result from a single driving force (e.g. inadequate transport policies may lead to an increase in motor vehicle injuries, effects on the respiratory system, and noise disturbance). Equally, multiple causes may contribute to a single health effect (e.g. acute respiratory infections in children resulting from a combination of diverse driving forces, such as poverty, household policies, household energy policies, etc.) (WHO, 1997). In both these cases, the DPSEEA framework needs to be extended and adapted to include these multiplicity of pathways and links.

Against this background, Table 3.1 shows examples of indicators for one environmental health issue (occupational lead exposure). Note that the term "descriptive indicator" is used in Table 3.1 to describe indicators of driving forces, pressure, state, exposure and health effects, in the DPSEEA framework. Action indicators refer to actions at each level of the framework. A matrix of environmental health indicators, based on major and common driving forces, is also given in Table 3.2. This shows the range of indicators which might be developed for different environmental health issues, for each link in the DPSEEA framework.

As these example imply, an important question in developing any environmental health indicator is at what position within the DPSEEA framework it should be targeted. In terms of environmental epidemiology, the focus of attention is often the link between exposure and effect, for it is at this point that the environment is seen to have an impact on health. For this reason, it might be expected that most environmental health indicators are likely to be either exposure or effect indicators. To some extent this is true. In terms of health policy and management, however, it is often the earlier links in the DPSEEA framework which are of most interest. Many environmental health problems derive ultimately from relatively remote causal forces and events. Immediate sources of exposure thus represent little more than symptoms of the problem. Desertification, for example, is often a consequence of deeper-seated social and economic causes. Pollution, equally, is often a symptom of inadequacies in industrial technology and policy controls. If the aim is to identify the underlying cause of the problem, and to take effective action at source, it is therefore essential to have indicators that allow the effects on health to be traced back to their underlying sources and causes.

Indicators from higher up the DPSEEA framework also tend to provide a better early warning both of impending environmental problems and of the effects of intervention. Detectable changes in the state of the environment and in human health, for example, typically lag some way behind changes in source activity or emissions and in the case of some effects, such as cancers, often by many years. Most preventative action, similarly, occurs at or close to the source of the hazard (e.g. by controlling emissions at source or through hazard management).

A further reason for relying on indicators from higher up the DPSEEA framework is practical and is that of data availability. Typically, data become more difficult to acquire with each step down the chain. Thus, while there are normally abundant data on social and economic conditions and trends, much

Table 3.1 Examples of indicators within the DPSEEA framework: occupational lead exposure

Stage	Process	Descriptive indicator(s)	Action indicator(s)
Driving force	Type of development or human activities	Industrial/occupational use of lead Mining of lead	Technological innovation affecting use of lead Education about hazards of lead
Pressure	Source activities	Specific uses of lead Lead consumption (quantity produced and recycled)	Trends in lead use profile Trends in quantity of lead used Substitution for lead
	Emissions	Contamination of occupational and para-occupational environment	Availability and use of control technology
State	Environmental levels	Airborne lead concentrations Lead dust concentrations (work and home)	Trends in ambient air and dust monitoring
Exposure	Human exposure	Blood lead Blood ZPP Personal air sampling	Surveillance of blood lead and ZPP Trends in personal air monitoring Education about hazards of lead
	Dose	Blood lead Bone lead (research tool)	Trends in blood lead (e.g. government registries)
Effects	Early/subclinical	Deranged haem synthesis Non-specific CNS symptoms Abnormal nerve conduction velocity	Application of special surveys based in the workplace
	Moderate/clinical	Abdominal and constitutional symptoms Anaemia Decreased renal function	Routine medical surveillance (employment-based)
	Advanced/permanent	Renal failure Peripheral neuropathy Encephalopathy	Periodic analyses of major morbidity and mortality Clinical interventions

ZPP Zinc protoporphyrin
CNS Central nervous system

Table 3.2 Environmental health indicator matrix (illustrative example)

Driving force	Pressure(s)	State	Exposure(s)	Effect(s)	Action(s)
Population changes and social conditions	Social, economic, and demographic characteristics	Birth rate Age distribution Income distribution	Proportion of population living in poverty Proportion of population in vulnerable age groups (in association with other exposures)	Mortality, morbidity and disability (in association with other driving forces)	Education (particulary female) Health care Birth control initiatives Income distribution Equity policies
Human settlements and urbanisation	Urbanisation and urban migration *Housing*	Overcrowding Garbage disposal *Noise levels* Indoor pollution: – chemical – physical – biological	Proportion of population living in disadvantaged areas *Proportion of time spent* indoors Proportion of population living in affected housing	Road accidents Crime rate Infectious diseases Mental health Neurobehavioural disorders Cancer Respiratory conditions	Service provision Health facilities Facilitate growth of smaller urban centres Improved housing
Water requirements	Quantity: – inherent scarcity – increased consumption Quality: – natural – pollution (sewage, industrial effluent, *urban run off and* agricultural run off)	Water supply and sanitation: – formal access – private systems (e.g. wells) – informal market Industrial use Agricultural irrigation	Proportion of population without access to sanitation Proportion of population with insufficient water Proportion of population buying water from vendors	Morbidity and mortality resulting from: – water-borne diseases (e.g. cholera) – water-washed diseases (e.g. trachoma) – water-based diseases (e.g. schistosomiasis) – water-related diseases (e.g. malaria) – water-dispersed diseases (e.g. legionella)	Water conservation measures Use of urban wastewater for irrigation Increase access to safe water/hygienic sanitation Pollution control legislation Community education

Table 3.2 Continued

Driving force	Pressure(s)	State	Exposure(s)	Effect(s)	Action(s)
Food and agriculture needs	Food production and diet Amount produced	Calories per person Extent of land degradation Availability of water	Proportion of children with lower than acceptable calorie intake	Malnutrition Lower rate of growth in children Lowered immunity (Risks mostly in developing countries, and particularly for children)	Improved access and distribution Health education
	Microbiological contamination	Presence of microorganisms (measurements)	Consumption of contaminated food	Diarrhoea, typhoid fever, cholera, shigella etc. (Risk to the general population)	Access to clean water Improved personal hygiene, sanitation and hygenic food production (e.g. pasteurisation and irradiation)
	Toxic agents Type and amounts of chemicals used	Chemical additives Heavy metal releases in the environment Pesticides Agricultural chemicals and organic wastes contaminating water supply	Population living in affected areas Use (or lack of) of protective equipment for workers	Accidental poisoning Suicides (Risk particularly to workers and population in developing countries)	Legislationand supervision Improved labelling Use of protective clothing and equipment
Energy demand	Use of fossil fuels for transport, industry and home use (type and amount used)	Concentration of air pollutants (e.g. SO_2, PM_{10}, CO, NO_x, ozone, lead, cadmium mercury, arsenic)	Proportion of urban dwellers Proportion of population living in areas where these pollutants exceed recommended levels	Respiratory conditions, carcinogenic effects and other pollutant-specific morbidity/mortality effects (Risk to urban population)	Abatement expenditure Legislation for transport and industry Increased research into alternative power sources (e.g. solar and wind)

Table 3.2 Continued

Driving force	Pressure(s)	State	Exposure(s)	Effect(s)	Action(s)
Energy demand	Use of biomass fuel for cooking and heating (type and amount)	Concentration of indoor air pollutants (e.g. SO_2, PM_{10}, CO, NO_X, hydrocarbons, aldehydes, cresol, acenaphthylene, benzene, phenol, toluene, polyaromatic hydrocarbons)	Proportion of time spent indoors and in cooking areas	Respiratory conditions, CO poisoning and risk of respiratory cancer Accidental burns (Risks to women and children in both urban and rural settings in developing countries)	Improved access to improved stove designs Use of processed biomass fuels Use of fossil fuels (gas)
	Use of nuclear energy (amount of radioactive material used)	Number and state of facilities Radiation levels	Personal monitoring (workers) Population living in surrounding areas	Leukaemia and other cancers	Safety measures in place
Industry development	Workplace (characteristics, type of industry, type and amount of hazardous materials used)	Workplace exposure levels (e.g. asbestos, silica dust, organic solvents, lead, mercury, cadmium, manganese, arsenic nickel, aromatic amines, benzene, and noise)	Monitoring exposures in the workplace, in work-specific areas and in individual workers	Occupational diseases and accidents	Emission control measures Chemical safety legislation Epidemiologic studies Improved labelling Improved supervision
	Accidental releases (quantified emissions)	Short-term, high concentration of toxic substances (in air and water)	Environmental measures in populated areas	Several, including poisoning and cancer risk	Disaster prevention/ preparedness measures Environmental health impact assessment

Table 3.2 Continued

Driving force	Pressure(s)	State	Exposure(s)	Effect(s)	Action(s)
Industry development	Toxic chemicals and hazardous waste disposal (quantified)	Nature and amounts of hazardous materials in the environment (measured)	Population living around hazardous waste disposal sites	Several potential health effects (pollutant-specific)	Legislation for safe disposal methods Supervision (e.g. against illegal dumping)
Global limits	Release of CFCs and other ozone-damaging chemicals	Stratospheric ozone depletion Solar ultraviolet radiation at ground level	Proportion of time spent outdoors in specific locations Use of (or lack of) protection	Skin cancers Ocular cataracts Immunosuppression	Legislation (Montreal Protocol)
	Release of "greenhouse gases"	Climate change: – temperature and precipitation change – increased climate variability – sea level rise	Population living in affected areas	Heat-related illness and mortality Redistribution and re-emergence of vector- and water-borne diseases New and re-emerging infections Large-scale negative effects on nutrition	Research Monitoring Legislation (Framework Convention on Climate Change)

CFCs Chlorofluorocarbons

less is known about the actual pressures on the environment, less still about environmental conditions and little about actual exposures. As a consequence, proxy indicators of exposure commonly have to be used that are derived from higher up the DPSEEA framework (Checkoway *et al.*, 1989).

The use of indicators from higher up the exposure chain, whether in their own right or as proxies, is not without its dangers. As noted earlier, to be effective any environmental health indicator must be based on a clear and firm relationship between the environmental hazard and the health effect. Unfortunately, the further removed the indicator is from the health effect, the weaker this link is liable to be. Each link in the chain is itself dynamic and uncertain; each step is subject to a wide range of influences and controls. The extent to which the driving forces are translated into active pressures on the environment, for example, depends upon the policy context, social attitudes and the pre-existing economic infrastructure of the area concerned. Whether these pressures cause detectable changes in the environment depends upon the ability of the environment to absorb and damp down the changes involved. Whether the environmental hazards, in turn, lead to health effects is determined by all the factors that control exposure and human susceptibility to its effects. It depends, therefore, on the form, duration, intensity and timing of exposure; on the social, economic and prior health status of the individuals concerned; and on the quality and accessibility of the health system. Equally, there is no certainty that action will be taken in response to the existence of environmental health problems. This depends not only on adequate recognition of the problems concerned, but also on political will, economic and technological capability and public acceptance of the actions involved. As a consequence, indicators from higher up the framework must be used and interpreted with care.

3.5 Conclusions

Population growth, technological and economic development, changing lifestyles and social attitudes, natural processes of change in the physical environment and the long-term impacts of past human interventions are all contributing to increasing problems of environmental health. To address these problems effectively, decision-makers require better information. This information needs to be reliable, consistent, targeted at the issues of real concern, available quickly, and available in an understandable and usable form.

Environmental health indicators provide one means of providing this information. In recent years, much progress has been made in developing indicators in a wide range of relevant fields and for many different applications. Progress in developing environmental health indicators has so far been slower, partly due to lack of consensus about the key issues that need to be addressed. There is, however, a growing need for environmental health indicators, both at the national and international level to inform broad-scale policy, and at the local scale in support of community- and city-level actions to improve and safeguard health.

Developing useful and effective indicators is a challenging task. Different users will have different expectations of the indicators they use, and a wide range of often competing criteria have to be met. The DPSEEA framework provides a useful means of rationalising the process of indicator design and construction. The next chapter considers the more technical issues involved in trying to apply these principles to indicator development in the area of environmental health.

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