Chapter 7. Framework for Linkages

In this chapter, a framework for considering linkages between health, environment and development issues is given. The framework is particularly useful for describing pollution-related health impacts, but can be applied in other contexts as well. Indicators at various levels in the framework could be selected for use at the global, national and local levels, in relation to particular problems, issues or policies and plans in countries.

7.1 DEVELOPMENT OF FRAMEWORKS

Decision-makers need not only better data on the linkages between the complexity of factors in the environment and development process affecting human health, but also enhanced understanding of such linkages. In terms of sustainable development, a framework is needed in which the various environmental, economic and social factors and components can be considered in a balanced way. A framework for presenting the linkages among factors that affect health in the context of environment and development has been adapted from the “pressure-state-response” (P-S-R) model developed by OECD, which in turn was based on earlier work by the Canadian Government.

The pressure-state-response (P-S-R) framework has been particularly useful in representing the way in which pollution affects the environment, for example by looking at the various “pressures” exerted on the environment which affect its “state” (quality) and consequently call for a “response” to deal with the situation. While this framework has been criticized as being linear and uni-directional, an adaptation of the framework by the Commonwealth of Australia (93), indicating the feedback loops in circular fashion, has proven useful.

Other adaptations to the P-S-R framework have provided for the broader driving forces and their impacts, resulting in the “pressure-state-impact-response” (P-S-I-R) framework, which takes into account human health, ecosystem and social-economic impacts (94).

D-P-S-S-E-A Framework

In the context of human health impacts, both exposures and the resulting health effects must be represented. These aspects are taken into account in a further adaptation of
Figure 18
PRESSURE-STATE-RESPONSE FRAMEWORK

Human subsystem
- economic subsystem
  - goods & services
  - labor
- population subsystem

Environmental subsystem
- pollution
- resource depletion

PRESSURE
natural feedbacks

RESPONSE

STATE

RESPONSE

Source: World Resources Institute (29)

Figure 19
MODIFICATION OF THE PRESSURE-STATE-RESPONSE FRAMEWORK

HUMAN ACTIVITIES AND IMPACTS
- Energy
- Transport
- Industry
- Agriculture
- Fisheries
- Others

STATE OR CONDITION OF THE ENVIRONMENT
- Air
- Water
- Land
- Resources
- Biodiversity
- Human Settlements
- Culture and Heritage

INSTITUTIONAL AND INDIVIDUAL RESPONSES
- Legislation
- Economic instruments
- New Technologies
- Changing community values
- International obligations
- Others

RESPONSE

Source: Commonwealth of Australia (93)
the framework for health purposes, referred to as the D-P-S-S-E-A framework (driving forces, pressures, state, exposures, health effects and actions), (22). This is a descriptive representation of the way in which various driving forces generate pressures that affect the state of the environment and ultimately human health, through the various exposure pathways by which people come into contact with the environment.

![Figure 20: PRESSURE-STATE-IMPACT-RESPONSE FRAMEWORK](source: Harvard University (94))

The D-P-S-E-E-A framework, like the P-S-R framework on which it is based, represents the components in a linear fashion in order to represent the connections between factors affecting health and the environment more clearly. In reality, the situation is more complex however, as various interactions occur at different levels between various components. The different components of the D-P-S-E-E-A framework are given in the figure below.

The framework takes account of the fact that, as already mentioned in Chapter 1, various factors responsible for health and environment problems may be associated with such driving forces as population growth, economic development, technological change and to the policies underlying them. Pressures may be exerted on the environment which cause development sectors to generate various types of outputs (for example in the form of pollutant emissions), causing the “state” (quality) of the environment to be degraded through the dispersal and accumulation of pollutants in various environmental media, such as air, soil, water and food. People may become “exposed” to potential hazards in the environment when they come into direct contact with these media, through breathing, drinking or eating. A variety of health effects may subsequently occur, ranging from minor, subclinical effects (i.e. effects that have
not yet manifested in overt symptoms) to illness and death, depending on the intrinsic harmfulness of the pollutant, the severity and intensity of exposure and the susceptibility of the individuals exposed. The elderly, the young and the sick may often be more susceptible than other groups.

Various actions can be implemented at different points of the framework and may take a variety of forms, including policy development, standard setting, technical control measures, health education or treatment of people with diseases.

The following sections give lists of indicators that could be used at various levels of the organizing framework, and which can be applied to information gathering and indicator development at the national or sectoral level, at the community or neighbourhood level or even at the level of an industrial enterprise (23). The framework is not rigid, and its applicability and usefulness will depend on the context in which it is used.

In many cases, consideration is given to more than one type of indicator for a similar issue, in order to illustrate the range of possibilities. The lists are not exhaustive but are meant to serve as a guide and stimulus for the selection of indicators that may be
appropriate for use in particular situations. Specific measurement variables and units of measurement will have to be further specified in almost all cases (see Chapter 4). Here, the indicators are given in “shorthand” in order to highlight issues. When appropriate and relevant, indicators should be disaggregated by sex, in order to address the gender dimension, and by other variables indicative of inequalities.

7.2 DRIVING FORCES

As already noted, a number of key factors on the macro scale broadly affect the environmental processes that may ultimately affect human health. For example, macroeconomic policies may have major effects on the environment and on people’s health. Trade and fiscal policies may indirectly impact on human health by affecting income levels and distribution, and agricultural or energy policy may affect health by impacting on land, air and water resources (95). It is often at this level of decision-making, i.e. higher up in the framework, that indicators are useful for setting and evaluating policies, as they allow examination of the root causes of problems, even if these are seemingly remote from the issue under consideration. Thus, if the aim is to take effective action at source, indicators that allow tracing of health effects to their underlying cause can be useful and can give an “early warning” of pending environmental problems. Waiting for actual health effects to occur may delay action, sometimes for years.

Another reason for using indicators at this level is that a certain amount of information is often available, whereas the necessary information becomes progressively more difficult to acquire as one moves down the framework. Information is usually more readily available on social and economic trends than, for example, on environmental conditions and health effects, but the links between environmental hazards and health effects become weaker and less direct as one moves higher up the framework.

Examples of indicators associated with driving forces which might be of use at this level of the development-environment-health framework are given below.

| Box 12 |
| EXAMPLES OF “DRIVING FORCE” INDICATORS |
| • Total fertility rate |
| • Population growth rate |
| • Urban growth rate |
| • Annual energy consumption levels |
| • GDP per capita and growth rate |
| • Income levels, distribution/trends |
| • Adult literacy rate |
| • Primary and secondary school enrolment rates |
| • Employment rate |

(cont’d)
7.3 PRESSURES

The various driving forces considered above may result in pressures on the environment. Many factors however, including policy context, social attitudes and economic infrastructure, affect the extent to which driving forces are translated into actual pressures on the environment. Pressures are generated by all sectors of economic activity, such as transport, energy, housing, agriculture, industry, tourism and so forth. Pressures can occur from resource extraction, processing of materials and the production, distribution, consumption and release of waste products. An important pressure from the point of view of human health is the release of pollutants into the environment. Many different sources and media such as water, air and soil may be involved.

As discussed above, health and environment indicators at this level of the framework are important for addressing the root causes of problems, such as the release of pollutants or wastes or certain infrastructural developments which may manifest themselves only much later as effects on the state of the environment. Nevertheless, constraints similar to those discussed above with respect to driving forces also operate at this level: for example, the ability of the environment to absorb the various stresses imposed on it influences the extent to which changes in the state of the environment result.

Box 13
EXAMPLES OF INDICATORS ASSOCIATED WITH VARIOUS PRESSURES

“Pressure” indicators: Air

- Number and type of polluting industries
- Levels of domestic consumption of gas, coal and biomass
- Production and consumption of ozone-depleting substances such as chlorofluorocarbons (CFCs)
- Consumption levels of leaded gasoline
- Average road traffic volume and density
- Annual emissions of:
  - sulfur and nitrogen oxides
  - particulates, toxics and heavy metals
  - carbon monoxide and volatile organic compounds (VOCs)
- Annual national and global emissions of greenhouse gases (for example carbon dioxide) by source
- Annual emissions from major industrial facilities by source
### Annual emissions from mobile sources, for example transport
- Annual emissions of radionuclides from nuclear facilities
- Emissions of chlorinated dioxins, furans, mercury and other harmful pollutants from waste burning facilities
- Accidental releases of toxic chemicals and radioactive substances

### “Pressure” Indicators: Water
- Availability of water resources per capita
- Water consumption by use per capita
- Domestic consumption of water per capita
- Water recirculation levels in industry
- Amount of fresh water and coastal waste water discharges
- Amount of industrial/municipal effluent (treated and untreated) discharged
- Tonnes of sewage discharged into water bodies
- Discharges of domestic and industrial waste-water into surface water

### “Pressure” Indicators: Waste
- Annual tonnage of hazardous and medical waste produced, by class
- Imports and exports of hazardous waste (tonnes/year)
- Toxic constituents of hazardous waste produced
- Amount of radioactive materials used
- Amount of municipal, agricultural, industrial and nuclear waste generated
- Annual amount of domestic waste produced/disposed of per household/per person
- Quantities of toxic chemicals in waste streams released, disposed of, treated or combusted for recovery
- Amount of untreated waste produced
- Amount of stored radioactive waste, by class
- Amount of radioactive waste not meeting waste disposal standards
- Amount of waste not collected, illegally dumped
- Proportion of hazardous wastes disposed to open dumps
- Proportion of sewage treated to secondary level
- Amount of waste re-used
- Percentage of domestic waste collected for recycling
- Frequency of waste collection in residential areas.

## 7.4 STATE

The state (quality) of the environment may be affected by the various pressures exerted. Some changes may be complex and widespread, affecting almost all aspects of the environment and resulting in effects such as desertification, marine pollution or climate change, while others may be more localized (for example, contamination of a local water supply). The frequency or magnitude of natural hazards may be increased (for example floods, soil erosion), natural resources may be negatively affected (for example biodiversity, soil fertility) or the quality of air and water may be affected by
pollution. Secondary effects may also occur, since modifications in one area may affect others. New health hazards may be generated at each step.

Box 14
EXAMPLES OF INDICATORS OF THE STATE OF THE ENVIRONMENT

“State” Indicators: Air
- Pollutant concentrations (for example sulfur dioxide, nitrogen oxides, ozone, particulates, lead) in urban air
- Concentrations of carbon monoxide and volatile organic compounds in urban air
- Number of hours/days per year during which pollutants exceed standards
- Total suspended particulates, PM$_{10}$/PM$_{2.5}$/black smoke exceedance of guidelines or standards
- Concentrations of ozone-depleting substances in air
- Global atmospheric concentration levels of greenhouse gases
- Indoor air pollution levels
- Annual number of severe pollution incidents

“State” indicators: Water
- Exceedance of standards and guidelines for:
  - drinking-water
  - recreational fresh and marine waters
  - aquaculture water
  - irrigation water
- Proportion of inland surface waters not meeting standards for the preparation of drinking-water
- Proportion of recreational surface waters not meeting bathing-water quality standards
- Faecal coliform levels in fresh water
- Percentage of rivers, streams, lakes and reservoirs providing water that is not safe for use without treatment
- Concentrations of nitrogen and sulfur oxides in precipitation
- Water hardness, colour, taste, pH, biological oxygen demand, chemical oxygen demand, optical density, total organic compounds, volatile organic compounds
- Concentrations of nitrates, nitrites, phosphates in drinking-water
- Levels of pesticide residues in drinking-water

“State” indicators: Other media
- Levels of radiation/radionuclides in environmental media
- Levels of lead, cadmium, arsenic, mercury in air; drinking-water; soil, dust, food
- Concentrations of polychlorinated biphenyls, dioxins in food, air, water
- Frequency of illegal pesticide residues in food and water
- Levels of faecal coliforms and Escherichia coli in food, water
- Area of land/number of sites contaminated by hazardous waste
- Community and occupational noise levels exceeding standards
7.5 **EXPOSURES**

Even where the state of the environment is unduly affected, people’s health and well-being may be affected only when they are actually exposed. Many factors determine whether an individual will be exposed, for example, to pollution in the environment. Pollution levels vary from place to place and over time, and people’s activities and behavioural patterns may influence the extent to which they come into contact with the environment. An environmental factor may play a major or a minor role in influencing a disease outcome. With low levels of exposure, the factors concerned may more often play a contributory rather than a primary role in causing disease.

Since many diseases are caused by a number of factors, it may be difficult to determine the effects of one exposure among others. Moreover, human beings are often exposed to mixtures of chemicals that are not well characterized. The effects of exposure to two or more chemicals or to a chemical and other harmful agents are not well understood.

The co-action of other factors may be required for significant effects to occur. In some cases, multiple exposures may result in a synergistic effect (where the combined effect is greater than the sum of the individual effects). Combined effects may often arise with nutritional and other lifestyle factors such as smoking and alcohol intake. Thus, for example, the incidence of lung cancer is higher in uranium miners and asbestos workers who are smokers than in workers with similar occupational exposures who are not smokers.

Exposure to chemicals is usually mediated by complex environmental pathways, and more than one route may contribute to uptake. People may be exposed through the air they breathe, the water and food they ingest or contact with the skin.

Exposure should be characterized and measured, indirectly as the concentration of the pollutant in the environment (taking the duration of exposure, peoples’ activity patterns into account), as an estimate of the amount that an individual actually ingests, inhales or absorbs, or as the amount that actually reaches a target organ where a health effect may occur.

While exposure in the occupational setting may be easier to characterize than exposure in the environmental setting, in both contexts it is often necessary to rely on proxies of exposures. These include such state of environment indicators as the concentration of pollution or pressure indicators even further removed from the exposure in question, such as emission rates, estimates of traffic volume, distance from a source such as a road or industry, or living in a home with smokers.

The concentrations of pollutants in the environment are often measured in order to detect peak levels, in assessing compliance with standards or guidelines. Monitoring may be carried out at places of little relevance to typical human exposures however, and in many cases only a few areas and substances are monitored. Knowledge of temporal and spatial variations in concentrations of substances are needed. For many pollutants, the concentration decreases sharply with distance from the source, and vertical and temporal variations may be found.
Improved biological and biochemical markers of exposure should enhance the effectiveness of exposure assessments in the future.

Whatever technique is chosen to characterize exposure, account must be taken of the exposure of groups at specific risk, which include the poor, women, children and workers.
Box 15
EXAMPLES OF DIRECT AND INDIRECT INDICATORS OF EXPOSURES

“Exposure” indicators: Air
- Proportion of population living in proximity of sources of air pollution (traffic, industrial activities)
- Proportion of population with elevated personal exposures to air pollutants such as particulate matter with a diameter of less than 10 micrometres
- Proportion of population exposed to elevated levels of pollutants in microenvironments, and estimates of time spent in different microenvironments
- Proportion of population exposed to air quality in excess of standards
- Proportion of population exposed to high levels of radon or of dust lead levels in their homes
- Proportion of population exposed to indoor pollution from burning coal or biomass
- Proportion of children exposed to high levels of environmental tobacco smoke
- Proportion of population who smoke (children, adolescents and adults)
- Carboxyhaemoglobin concentrations in blood
- Proportion of population with raised blood lead levels

“Exposure” indicators: Water
- Proportion of population whose homes are not connected to a water supply system (urban versus rural)
- Proportion of population served by drinking-water systems without source water protection
- Proportion of population without access to safe drinking-water
- Proportion of population whose drinking-water supplies do not meet health standards
- Proportion of population not receiving safe water in the home (or within 15 minutes’ walking distance of the home)
- Proportion of population with no safe drinking-water within reasonable walking distance

“Exposure” indicators: General
- Proportion of population living in poor housing conditions
- Proportion of population homeless
- Proportion of population living in substandard housing
- Proportion of dwellings disconnected from water, electricity, gas supplies
- Average number of persons per room in occupied housing units, distribution according to density
- Proportion of population without access to a sewerage system, septic tank or other hygienic means of sewage disposal
- Proportion of population with inadequate sanitation facilities in the home or immediate vicinity
- Proportion of population with inadequate excreta disposal facilities
- Proportion of population with raised blood lead levels

(cont'd)
• Proportion of population exposed to persistent organic compounds, for example aldrin, dieldrin, chlordane, DDT, endrin, heptachlor, hexachlorobenzene, polychlorinated biphenyls, dioxins, furans
• Proportion of workers exposed to hazardous working conditions, by class type
• Proportion of workers exposed to unsafe levels of dusts, fumes or gases in the work place
• Proportion of workers exposed to noise levels above safety standards

7.6 HEALTH EFFECTS

Once a person has been exposed to an environmental hazard, health effects may manifest themselves which may vary in type, intensity and magnitude depending on the type of hazard, the level of exposure and other factors. The ill-health effects of environmental exposures may be acute, occurring relatively soon after exposure (from a single large dose due to an accident or a spill for example), or they may be chronic, occurring as a result of cumulative exposures over time. A long time may elapse between the initial exposure and the appearance of the adverse health effect, for example exposure to asbestos and mesothelioma, or exposure to radiation and leukaemia. Dispersal of the population at risk over time and the long incubation period make reconstruction of exposures problematic, so that acute health effects are often easier to detect than chronic ones, which may be difficult to relate to specific hazards or sources.

While almost any substance can cause harm if taken into the body in sufficiently large amounts, the substances of frequent concern are those which may have adverse health effects even at relatively small doses. A hierarchy of effects may occur, ranging from minor, temporary ailments to acute illness or chronic disease, with relatively resistant and susceptible persons at either extreme of the distribution. Infants and young children may be at high risk, as they take in more of a contaminant in relation to their body size than do adults and have immature and therefore particularly vulnerable physiologies. The unborn fetus is especially susceptible to toxic chemicals. Elderly people are also vulnerable from a physiological point of view, and may be more susceptible to lung infections than young people. The vulnerability of individuals (as opposed to groups) may also vary over a wide range.

Thus generally speaking, many factors affect the extent to which a hazard in the environment affects human health. The form, duration, intensity and timing of exposure are important, as is the health status, age and genetic make-up of the individual, as well as the quality and accessibility of the health care system.

Health Risk Assessment

In assessing health risks from environmental exposures, reliance is placed on
Chapter 7. Framework for Linkages

epidemiology and toxicology. Environmental epidemiology is concerned with health effects in populations which result from exposures to environmental factors under conditions of “daily living” (99), while toxicology involves studies of the effects of potentially toxic substances on human beings or animals under controlled conditions. Such studies are needed to identify the toxicity of substances in advance, but it is often necessary to extrapolate from studies on laboratory animals at high doses to low doses and then to human populations. Many assumptions are involved. Results obtained in animals are not necessarily applicable to human beings, and it is usually not possible to reproduce all the potential contributing factors in the laboratory.

Although general indicators of ill-health may not be very useful, certain diseases may indicate environmental problems. “Sentinel” diseases or conditions which are rare can often be more readily related to an external factor. Examples include mesothelioma as an indicator of exposure to asbestos, silicosis as an indicator of exposure to silica dust and lung cancer as an indicator of exposure to tobacco smoke.

Examples of health indicators that might suggest environment-related disease are given below. Sometimes, health indicators might be developed for specific groups at risk, such as women and children, the elderly, the disabled or the poor. The significance of any individual indicator depends on the exposure concerned and the context of the issue or problem being addressed. In describing any one health issue or problem, sets of indicators would normally be compiled from those listed at various levels of the framework.

Box 16
EXAMPLES OF HEALTH EFFECT INDICATORS

Environment-related (or suspected)
- Number of outbreaks of foodborne disease (for example Salmonella, E. coli, listeria) and waterborne disease (for example cholera, typhoid, giardia, shigella)
- Work-related mortality and morbidity (for example in respect of asbestosis, mesothelioma, silicosis, heavy metal poisonings, fatal and non-fatal injuries)
- Mortality and morbidity associated with motor vehicle accidents
- Number of deaths from drowning
- Mortality and morbidity associated with non-work-related injuries and poisonings (for example pesticides)
- Environment-related cancer morbidity and mortality (for example lung cancer in non-smokers)
- Morbidity and mortality associated with typhoid, malaria, polio, cholera, hepatitis A and other infectious/parasitic diseases
- Morbidity and mortality associated with diarrhoea in young children
- Morbidity and mortality associated with acute respiratory infections/pneumonia in young children
- Morbidity and mortality associated with asthma
- Mortality and morbidity associated with chronic respiratory disease

(cont’d)
7.7 ACTIONS

An approach to the control and prevention of health hazards which focuses on hazards of human origin is useful in that it addresses potentially remediable problems. This approach however must be adopted with due regard for the still considerable uncertainty that exists about the extent of the direct and indirect risks to human health associated with specific agents in the environment or with the broader development process.

While in some instances the hazards in question are known and identified, the contrary is often the case. For many substances, it is not known whether there is a threshold for an adverse effect and, if so, what that threshold is. Much environment-related disease goes unrecognized. Certain cancers and “subtle” diseases and disorders such as intelligence impairment caused by exposure to lead during childhood may not be recognized as being due to environmental factors.

While sound public policy is based on analyses of the best available information, it does not require absolute scientific certainty. Different actions can be taken, targeted at various points in the framework. It would obviously be impossible to reduce all environmental exposures to a level at which the risk to human health is zero. Measures to improve public health must be implemented over time. Such measures may be short-term and remedial or longer-term and preventive (for example changing personal behaviour and life styles). Measures could take the form of a policy or comprehensive plan of action (see preceding chapters on the planning process), which outlines the goals to be achieved in improving health and the environment and mechanisms for
attaining those goals, such as standards. A prudent policy on acceptable exposure levels is important, however, and such policies should be revised and updated in accordance with new scientific knowledge. This may lead in some cases to the introduction of more stringent standards, while in other cases the standards may be shown to have been unnecessarily restrictive.

The management of health hazards might be improved in other ways, apart from setting standards or guidelines and using improved technology and control measures to attain them. Education and raising the awareness of individuals about the risks to which they are exposed and the personal opportunities that exist for avoiding and reducing these risks, is particularly relevant. The public perception of risks often differs from that of scientists and regulators. Risks that are familiar may be less threatening than those which are unfamiliar, and people may be more willing to accept a risk that they believe they can control, especially when they may derive a direct benefit from doing so.

Various actions should thus be taken, based on consideration of the nature of the risks, their amenability to control and the public’s perceptions of the risks. Indicators of such actions do not illustrate an effect on the environment but reflect efforts to improve the environment and human health.

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**Box 17**

**EXAMPLES OF “ACTION” INDICATORS**

**Policy and planning**
- Health and environmental policies and action plans in place at different levels
- Existence of a national sustainable development strategy
- Emergency preparedness plans for health and the environment
- Policies in place on the import, use, emission and disposal of toxic chemicals
- Measures taken to incorporate health issues in national environmental plans, and in sustainable development plans
- Measures taken to incorporate health and environmental issues in plans for such sectors as energy, transport and agriculture
- Existence of a ministry of the environment
- Formal mechanism or structure in place for involving major groups and partners in policy development at different levels
- Existence of legislation on:
  - Environmental/health impact assessment
  - Use of safety belts
  - Air, water, food standards, guidelines, regulations
  - Ratification of global agreements/conventions on health and the environment
  - Laws, regulations, bilateral and multilateral agreements for the control of transboundary pollution and the international transport of hazardous substances

(cont’d)
Service delivery and research

- Environmental and occupational health service delivery coverage and provision
- Annual number of inspections, statutory notices served, prosecutions
- Existence of monitoring and surveillance systems for environmental health hazards, including:
  - Evaluation and surveillance of food safety (for example HACCP)
  - Monitoring the generation, transport and disposal of hazardous wastes
  - Air monitoring (stationary and personal sampling)
  - Surface, ground and drinking-water surveillance
  - Tracking sentinel environmental diseases
  - Integrating health and environmental information
- Percentage of GDP spent on health and environmental health
- Environmental health expenditure as percentage of the total health budget
- Environmental health component of public health programmes
- Number and nature of school education programmes on the environment and health
- Number and nature of public education programmes on the environment and health
- Number of research institutes and universities involved in environmental health research
- Proportion of the health research budget spent on environmental health