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# HUMAN SETTLEMENTS

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**T**he quality of the environment is inextricably linked to conditions in human settlements that ultimately affect the quality of life values of the people. Important considerations are the quality of housing and water supplies, facilities for sewerage and drainage, energy and transport, as well as the spatial distribution of housing. Careful examination of human settlements has shown that there is a strong relation between poverty and inferior environmental quality (especially in large urban settlements). Typically, the quality of the environment is poorest in slums, dilapidated neighborhoods, and squatter settlements.

Over the next few decades, many developing countries will see increases in their urban population that are roughly equivalent to the growth of the total population. Such trends ensure that the issue of environmental conditions in human settlements will assume even greater significance in the future. Moreover, a deterioration in the urban environment can have economic as well as social repercussions. The bulk of economic activity takes place in urban areas and a worsening of environmental conditions in this sector can jeopardize a country's

economic prospects. Policies to improve environmental conditions in human settlements are urgently needed, but they cannot succeed without a strong program of statistics on human settlements.

The subject of human settlements embraces a wider range of issues than does air or water. The first section of this chapter briefly discusses the main issues. This material draws on the work of the United Nations Conference on Human Settlements (UNCHS) and the goals set out in Agenda 21, which deals with the planning and management of human settlements, the provision of environmental infrastructure, and related concerns. The second section examines the organizational and methodological issues.

## Key Issues

A multitude of factors affect environmental conditions in human settlements and their interaction requires that a fairly comprehensive statistical effort be mounted. The key subject areas are noted in this section, but statisticians may find it necessary to add to or subtract from this list, depending on local conditions and priorities.

**Housing.** One of the goals of Agenda 21 is to provide adequate and environmentally sound shelter for the rapidly growing populations of developing countries, particularly the rural and urban poor. Information on this subject is collected via population and housing censuses. Household surveys are another useful tool because they can be tailored to address specific topics such as living conditions in human settlements. Housing statistics generally refer to the type of housing unit or living quarters, tenant arrangements, available facilities, and construction materials used. Concepts and classifications vary slightly from country to country. Some general definitions of these indicators are set out below:

- (i) Housing units are separate and independent places of abode. Most units are intended for habitation by one household. Some may not be intended for habitation, but are nevertheless

occupied as living quarters. Housing units are further subdivided into conventional and unconventional dwellings. A conventional dwelling refers to a room or cluster of rooms in a permanent building, which is meant for habitation. A conventional dwelling may be occupied or vacant. Unconventional dwellings are units not considered appropriate for habitation, but are nevertheless occupied. This category includes marginal housing units such as improvised houses, housing in buildings not intended for habitation, squatter settlements, slums, and makeshift shelters constructed of waste materials.

- (ii) Collective living quarters are units intended for habitation by a number of individuals or several households. Hotels and lodging houses are examples.
- (iii) Institutions are defined as permanent structures designed to accommodate groups of people. Examples are hospitals, military barracks, schools, hostels, and prisons. Also included in this category are camps intended as temporary accommodation for refugees, workers, and military personnel.

Tenure refers to the status of the occupant of the dwelling. An owner-occupant owns the unit he occupies, even though he may be paying a loan or mortgage on the unit. A tenant or renter occupies a housing unit, which is not his property. Indicators of materials used for construction usually distinguish between the materials used for external walls and those for the roof. If the walls are constructed of more than one material, the predominant material is usually indicated.

A number of indicators can be used to identify facilities in a housing unit or living quarters. They include the following:

- (i) Cooking facilities generally refer to a kitchen where meals are prepared and the room is intended for that purpose. If

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some space in the unit is used to prepare meals but is not a room, it is denoted as “other space reserved for cooking.” Should the unit have neither type of facility, it is referred to as a unit “without kitchen or other space reserved for cooking.”

- (ii) Means of heating refers to the system used to heat the premises. It may be a communal or central heating system in a building with several units. The type of fuel used is also identified.
- (iii) Water supply system refers to the provision of water to housing units by pipes from community-wide systems or from individual installations such as pressure tanks and pumps. The categorization “with piped water” implies water supply “inside the housing unit,” or “outside the housing unit” but within 100 meters of the door.
- (iv) Waste disposal facilities have two categories. Housing units are designated as “with toilet of any type” or “without toilet of any type.” The usual types of toilets are common sewerage, pit latrine, and septic tank.
- (v) Other facilities include the cooking fuel used for preparing the principal meals, bathing facilities either within or outside the housing unit, and lighting identified according to the source of lighting for the housing unit.

Another popular measure is the number of persons per room in occupied housing. This statistic, however, is of limited use since it does not include information on room size, quality of construction, or related factors. Nor does it serve as a reliable indicator of overcrowding because the definition of a room varies and differences in room size are not considered.

**Land use in human settlements.** Undisciplined growth of urban centers threatens access to land owing to the increasing spatial

requirements of housing, industry, commerce, and transport, as well as the need for open spaces. Environmentally sound physical planning is necessary to avoid these problems. The process of land mapping and land titling has also fallen far behind the pace of growth of human settlements, delaying the start of development activities. Ineffective land use and poor planning have resulted in chaotic urban growth and the unnecessary use of agricultural land for physical development. Statistics on land use provide an indication of the major categories of human activities carried out in different areas of human settlements. These data describe the geographic distribution of activities in so far as they are reflected in the character of built-up land. However, it is not possible to assess the level or intensity of activities from land use statistics.

**Urbanization.** The urban sector is where most economic activity takes place and where most pollution occurs. An accelerating pace of urbanization, along with higher rates of rural-to-urban migration, signal the onset of a number of environmental problems such as air, water, and noise pollution; shortages of necessary public amenities, and so on. Proper planning and management of urban growth require accurate and timely statistics. In many developing countries, the existing data is not adequate to provide an overall picture of the urbanization process and its consequences.

**Environmental infrastructure.** The provision of adequate environmental infrastructure and services—water, sanitation, drainage, and solid waste management—is crucial for improvements in the health and quality of life in human settlements. To a large extent, the presence or absence of these facilities determines the quality of a human settlement. Their presence is also an important means of boosting productivity. For these reasons, data on access to environmental infrastructure and services must be available in some detail.

Drainage and solid waste management are other serious problems in many cities. Authorities are frequently unable to remove more than a portion of the solid waste generated each day. Water disposal systems and storm water drainage are inadequate, particularly in low-income settlements. Few developing countries collect data on either of these aspects. Effective waste management requires an elaborate system of supervised disposal sites, trained personnel, equipment, vehicles, and

adequate enforcement mechanisms that many cities cannot afford. Even when reliable data on waste generation exists, the figures are not easily translated into management data. Some wastes are disposed of improperly or illegally, resulting in contamination of soil, groundwater, or air.

**Energy usage.** An adequate supply of energy is essential for human development. Industrial and commercial activities are the largest consumers of commercial energy in urban centers. The household sector typically accounts for around 25 percent of this total. Improvements in the efficiency of energy usage by households are therefore an important step. Households are also the largest users of noncommercial energy in developing countries. Fuelwood is the preferred source. Unless alternative fuels are available, the poor in human settlements will continue to rely on biomass fuels. Dependence on such sources can lead to deforestation, soil erosion, and desertification.

**Transport.** The main concerns relating to transport were discussed in terms of air pollution in Chapter 4. Transportation has impacts on the environment of human settlements. It also affects the physical patterns of settlements, access to infrastructure and services, and congestion. Proper environmental management of urban centers can ensure that adequate transport is available while minimizing its negative effects. However, a large amount of information is required in addition to that discussed in connection with problems of air pollution. Both ad hoc and periodic transportation surveys will be essential for planning and managing urban systems.

**Construction activities.** These activities are one of the major factors distinguishing the “human-made” environment from the natural environment. They affect land use, population density, the availability and quality of housing, utilities, and infrastructure. Building materials frequently account for as much as two thirds of the resources used in the production of shelter and infrastructure in developing countries. Accordingly, construction places a heavy demand on a country’s resource base. It is highly desirable that the industry use raw materials that are cheap, durable, and affordable. Unfortunately, little data is available to assess many of the environmental consequences of construction activities. Methodologies vary and there are no standards for data collection.

***Population growth and change.*** Both population growth and rural-to-urban migration strongly influence the demand for shelter, infrastructure, and related services. Much of this migration can be attributed to the especially poor quality of housing, education, and environmental infrastructure in rural settlements. Another reason is that the economic prospects of workers in urban areas are generally superior to those in rural areas. Frequently, the flood of migrants to urban centers overloads the existing housing and infrastructure in major cities.

## Organization and Methodological Issues

Clearly, a large number of statistical topics, indicators, and classification schemes are relevant for a statistical evaluation of human settlements (Table 6.1). Not all can be addressed in this Handbook. The efficient organization of all this material from multiple sources is a complex task, but the job can be simplified by constructing an FDES as described in Chapter 3. An example of an FDES is in Table 6.2, which lists several statistical topics grouped together according to common characteristics (in italics). The focus is on environmental impacts and the activities that give rise to these impacts. Other factors that do not directly influence the environmental aspects of human settlements, but are related to activities that do, are treated as background conditions.

In addition to the FDES, there are several methodological issues that must be addressed at an early stage in the program. These include

- (i) the distinction between rural and urban settlements;
- (ii) the identification of marginal housing units, for example, slums or squatter settlements; and
- (iii) resolution of problems of data compatibility and data currency.

Table 6.1: A Summary of Topics and Indicators for Human Settlement Statistics

Topic	Variable (unit of measurement)	Definition/Explanation	Classification	Likely Sources
1. Population growth and change	Average rate of change in population (percent) Net migration (per thousand)	The difference between gross immigration and gross emigration		Population census, surveys, projections and estimates Population census, surveys, projections, estimates, and civil registration
2. Construction of shelter and infrastructure	Housing units (number)	See text	By structure: conventional, unconventional, etc. By type of building activity: new, restoration, or conversion By type of investor: public, private, informal	Housing census and surveys, building permits, special surveys of the informal sector

Table 6.1: A Summary of Topics and Indicators for Human Settlement Statistics (continued)

Topic	Variable (unit of measurement)	Definition/Explanation	Classification	Likely Sources
	Decrease in housing stock (number)	Owing to conversion, demolition, destruction by natural disasters, and other activities (e.g., military action)	Reasons for decrease: conversion, demolition destruction by fire, flood, or other activities	
3. Transport	Road vehicles in use (number)		By type of vehicle: commercial or private passenger cars, trucks, buses, trams, etc.	Motor vehicle registration records
4. Land use	Settlement land area (square kilometers)	See footnote <sup>a</sup>	By type of land use: residential, industrial, commercial, motorways, recreational, open land	Municipal and administrative records, land surveys, aerial surveys
	Area of marginal settlements	See footnote <sup>b</sup>		

Table 6.1: A Summary of Topics and Indicators for Human Settlement Statistics (continued)

Topic	Variable (unit of measurement)	Definition/Explanation	Classification	Likely Sources
5. Emissions and waste discharges	Air pollution (tons)	See Chapter 4	See Chapter 4	See Chapter 4
	Solid waste collected (cubic meters, tons)	Solid waste and sludge generated by treatment plants	By type of solid waste: agricultural, industrial, mining, special hospital waste, radioactive waste, households	Ad hoc surveys, municipal records
6. Housing	Occupants (number)	See text	See text	Population and housing census, housing surveys and household surveys
	Rate of occupancy (number)	Average number of persons per room		Population and housing census, housing surveys, and household surveys

Table 6.1: A Summary of Topics and Indicators for Human Settlement Statistics (continued)

Topic	Variable (unit of measurement)	Definition/Explanation	Classification	Likely Sources
7. Access to infra-structure	Settlements supplied with electricity (number)	Settlements with more than 50 percent of housing units having access to electricity		Municipal records
	Households with water (number)		By distance to water supply: inside hose, within 100 meters of house, more than 100 meters away	Population and housing census, household survey, municipal records
	Households with access to sanitation (number)		By type of sanitation system: community sewerage, individual system, other	Population and housing census, household survey, municipal records
	Households with electricity (number)			Population and housing census, household survey, municipal records

Table 6.1: A Summary of Topics and Indicators for Human Settlement Statistics (continued)

Topic	Variable (unit of measurement)	Definition/Explanation	Classification	Likely Sources
	Average time spent travelling from home to work place (minutes)		By type of transport: public road or rail, private motorized, others	Household survey, transportation survey
8. Sprawl and dispersion	Primacy rate (percent)	Ratio of the largest city's population to the sum of the populations of the four largest cities		Population and housing census
9. Policies and programs	Expenditure for human settlement development (monetary units)	Financial resources spent for improvement in conditions of human settlements	By type of program: housing, rehabilitation of marginal settlements, land development, infrastructure	National accounts, development plans

**Table 6.1: A Summary of Topics and Indicators for Human Settlement Statistics (continued)**

Topic	Variable (unit of measurement)	Definition/Explanation	Classification	Likely Sources
	Community development programs (number)		By type: planning and design, implementation and management, general organization	Development plans
	Violations of building codes and regulations prosecuted (number)		By type: structural, health, fire, public safety	Municipal and legal records

<sup>a</sup> Settlement land use is defined as the occupation of houses, roads, mine and quarries, and other facilities deliberately installed for the pursuit of human activities.

<sup>b</sup> There is no generally accepted means of distinguishing between marginal settlements and other residential areas.

Source: Adapted from UN (1988).

**Table 6.2: A Sample Framework for Development of Environment Statistics for Human Settlements**

Social and Economic Activities	Environmental Impacts of Activities	Responses to Environmental Impacts	Stocks, Inventories, Background Conditions
<u>Growth and change in human settlements</u>	<u>Conditions of shelter, infrastructure, and services</u>	<u>Policies and programs</u>	<u>Stocks of shelter and infrastructure</u>
Population growth and change	Housing	Pollution monitoring and control	Housing stock
Construction of shelters and infrastructure	Access to infrastructure and services	Environmental standards	Nonresidential buildings, other physical infrastructure
Utilities (energy and water supply)	Human settlements sprawl and dispersion	Monitoring	<u>Environmental inventories</u>

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A geographic breakdown of the data is essential for environmental analysis. Administrators of particular settlements seek a full set of data for each settlement under their responsibility, but the focus of attention in this chapter is on the information needs of national planners and policy makers. Some classification of human settlements that can be applied throughout the country is required.

The most common approach is to identify settlements as rural or urban. However, the characteristics that differentiate these two types of settlements vary widely within the country and there is no generally accepted method of resolving the confusion. One alternative is to compile

**Table 6.2: A Sample Framework for Development of Environment Statistics for Human Settlements (continued)**

Social and Economic Activities	Environmental Impacts of Activities	Responses to Environmental Impacts	Stocks, Inventories, Background Conditions
Transport	<u>Conditions of life-supporting services</u>	Treatment, disposal, and reuse of discharges	Emission inventories
Land use	Ambient concentration of pollutants and wastes	Expenditure for pollution control	<u>Background conditions</u>
<u>Other activities</u>	<u>Health and welfare conditions in human settlements</u>		Land use
Emission and waste discharge	Exposure and health effects		Demographic and social conditions

Source: Adapted from UN (1988).

data for the capital city and the three other largest cities or urban agglomerations. If the available statistics do not coincide with the “administrative boundaries” of the city (that is, boundaries defined according to legal or political statutes for the city), data may be given for the “urban agglomeration.” This concept includes not only the administrative city but also the suburban fringe or heavily settled territory lying outside, but adjacent to, the city’s boundaries. Another approach is to show data for major cities and other selected settlements classified by population size.

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The identification of marginal housing units, slums, and squatter settlements is an issue not adequately covered by the statistics and indicators discussed in the chapter. Slums generally refer to older housing, which is underserved, overcrowded, and dilapidated. Squatter settlements are areas where housing units have been constructed on land to which the occupants have no legal claim. These types of settlements are usually located in suburban areas, particularly at the peripheries of principal cities. Housing censuses and environment statistics on human settlements usually combine slums and squatter settlements together under the heading of marginal housing. Sometimes, marginal housing units are further divided into subgroups: (i) improvised housing units, (ii) housing units in permanent buildings not intended for human habitation, and (iii) other premises not intended for human habitation. Whatever the treatment, statisticians should not lose sight of the fact that the economic and environmental impact of these settlements can be significant.

The periodicity of data collection is another general issue that must be addressed. Most statistics are presented on an annual basis, but environment data is collected over many different time periods, ranging from decades in the case of censuses to hourly, daily, monthly, or even continuous monitoring. One of the statistician's tasks is to process this data for annual presentation. However, annual presentation should not preclude the display of monthly or daily statistics where seasonal or other fluctuations are relevant. In some cases, it may not be possible to present annual data due to the periodicity of (infrequent) censuses or surveys.

## OUTLINE FOR THE PREPARATION OF A COMPENDIUM OF ENVIRONMENT STATISTICS

For purposes of illustration, the outline assumes that the framework chosen for organization of the data and tasks is one based on an environmental medium.

### Section A

1. Introduction
  - a. Country background, with brief outlines of physiography, biodiversity, and socio-economic conditions
  - b. Overview of the status of environment statistics in the country
2. Description of each of six environmental components (atmosphere, water, land/soil, flora, fauna, human settlements) under each of four information categories (social and economic activities and natural events; impact; response; and stocks, inventories, and background conditions).

Each chapter or section should contain textual description (supported by summary tables, charts, bars, and diagrams). The textual description in each section may focus on the following:

- a. A country overview of the individual environmental component
- b. Major problems associated with individual components indicating prime sources/causes of environmental degradation (natural such as flood, drought, earthquake, cyclone, volcanic

## Appendix 1 (continued)

- activity, etc.; and anthropogenic factors such as industries, urbanization, agriculture, vehicular traffic, etc.)
- c. Government or private efforts (such as environmental rules/regulations/ guidelines formulated and/or programs undertaken, etc.) made to mitigate the impacts, data availability, etc.

**Section B:**

This section is tabular, providing detailed data that supports the text in Section A.

**Section C:**

This section should contain the following appendices:

Names of agencies/data sources

Glossary of terms and abbreviations used

Brief outline of the methodology of environmental data collection  
indicating the duration and frequency of monitoring

Relevant standards

Relevant rules, regulations, acts, policies for protection of the  
environment and natural resources

References and bibliography

## TWO EXAMPLES OF A FRAMEWORK FOR THE DEVELOPMENT OF ENVIRONMENT STATISTICS

Example No. 1

Environmental Component	Social and Economic Activity	Environmental Impact of Activities	Response to Impact	Inventories, Stocks and Background Conditions
1. FLORA	Agricultural and livestock production (includes land clearing, irrigation, grazing, harvesting, use of fertilizers, and pesticides)  Forestry and logging	Proliferation, depletion, extinction of species	Protection of endangered species	Inventory of species and genetic resources  Inventory of vegetation cover (e.g., forest inventory)

Appendix 2 (continued)

Environmental Component	Social and Economic Activity	Environmental Impact of Activities	Response to Impact	Inventories, Stocks and Background Conditions
	Competing land use (settlements, agriculture, forestry, mining, recreation, etc.)	Impact of pollution on vegetation cover (e.g., from acidic precipitation)	Forest management including afforestation	Inventory of emissions hazardous to flora
	Emissions hazardous to flora	Impact on land/soil (desertification and erosion due to removal of vegetation cover, biochemicals in soils)	Pollution monitoring and controls	Land use and characteristics
		Changes in water regime from deforestation and removal of vegetation	Health protection (food quality controls, alternative food resources)	Socioeconomic factors affecting flora (population, food and energy production and consumption)
2. FAUNA	Livestock production	Proliferation, depletion, extinction of species	Hunting, fishing, and breeding regulations	Inventory of species and genetic resources

## Appendix 2 (continued)

Environmental Component	Social and Economic Activity	Environmental Impact of Activities	Response to Impact	Inventories, Stocks and Background Conditions
	Hunting, trapping, and game propagation	Migration of species	Protection of habitat (land-use regulations and zoning)	Inventories of habitats/ecosystems
	Competing land use (agriculture, ranching, settlements, etc.)	Changes of habitats/ecosystems (including species diversity)	Pollution monitoring and controls	Inventory of emissions hazardous to flora
	Emissions hazardous to fauna	Human health and welfare impacts (nutrition-related effects, changes in cost/productivity in livestock production)	Health protection (food quality controls, alternative food resources)	Socio-economic factors affecting flora (population, food and energy production and consumption)
3. ATMOSPHERE	Land use affecting climate (deforestation, desertification, drainage, irrigation, urban sprawl, infrastructure)	Air quality (ambient concentrations of air pollutants)	Monitoring and control of air pollution	Emission inventory (types, sources of air pollutants)

## Appendix 2 (continued)

Environmental Component	Social and Economic Activity	Environmental Impact of Activities	Response to Impact	Inventories, Stocks and Background Conditions
	Emission of air pollutants from stationary and mobile sources (industry, agriculture, households, transportation)	Biological and ecological impacts (contamination and destruction of species, disruption of ecosystems by acidic precipitation for example)	Alternative land use production processes and consumption patterns (e.g., alternative energy sources)	Inventories of areas vulnerable to air pollution and climate/weather extremes
		Impact on land, water and artifacts (e.g., acidic precipitation)	Health protection	Land use and characteristics
		Human health and welfare impacts (e.g., associated with air pollution)		Socio-economic factors affecting air quality and weather (population, food and energy production and consumption)

Appendix 2 (continued)

Environmental Component	Social and Economic Activity	Environmental Impact of Activities	Response to Impact	Inventories, Stocks and Background Conditions
4. WATER				
a. Freshwater	Water withdrawal (surface water, ground water, other)	Water quality (levels, flow and supply)	Conservation and development of water resources for industry, agriculture and domestic use (including water restoration)	Inventory of water resources
	Water use (industrial, domestic and municipal, agricultural)	Ambient concentrations of biological contaminants, chemical substances and suspended solids and physical characteristics	Water treatment (primary, secondary, tertiary)	Inventory of aquatic ecosystems
	Instream water use (hydro-power generation, transportation, fishing)	Biological and ecological impact (e.g., eutrophication, contamination and destruction of biota)	Conservation of aquatic ecosystems and their biota	Emission inventory (types, sources of discharges/ water pollutants)

Appendix 2 (continued)

Environmental Component	Social and Economic Activity	Environmental Impact of Activities	Response to Impact	Inventories, Stocks and Background Conditions
	Waste water and discharge (includes sedimentation)	Quality of precipitation, erosion, salination, flood, and drought areas	Pollution monitoring and water quality control	Land use and characteristics (e.g., vegetation cover, built-up area, soil types, vulnerability)
		Health and welfare impact (water-borne diseases, productivity/cost changes in water-using activities)	Health protection	Socio-economic factors affecting water use (population growth, density and migration, production and consumption, infrastructure, water budgets)
b. Marine water	Non-consumptive water use (tidal energy generation, transportation, fishing, etc.)	Ambient concentrations of pollutants (marine waters and coastal areas)	Conservation and development of marine waters and coastal areas (e.g., marine parks and reserves)	Inventory of ecosystems (marine/coastal) and species

Appendix 2 (continued)

Environmental Component	Social and Economic Activity	Environmental Impact of Activities	Response to Impact	Inventories, Stocks and Background Conditions
	Waste withdrawal and use (desalination, consumption)	Biological and ecological impacts (proliferation, depletion, extinction and contamination of marine biota, disruption of habitats)	Conservation of marine/coastal ecosystem	Emission inventory (types, sources of marine water pollutants)
	Competing coastal land use (infrastructure, tourism, recreation)	Human health and welfare impact (e.g., water-borne diseases, impacts of tourism, recreation)	Pollution monitoring and control	Coastal land use and characteristics
	Seabed mining (including offshore oil drilling)			Socio-economic factors affecting water use (population growth, density and migration, production and consumption, infrastructure, water budgets)
	Emissions from coasts and rivers, sea-dumping, oil spills			

## Appendix 2 (continued)

Environmental Component	Social and Economic Activity	Environmental Impact of Activities	Response to Impact	Inventories, Stocks and Background Conditions
5. LAND/SOIL a. Surface	Land use (agriculture and livestock, forestry and logging, mining and quarrying, human settlements, transportation, etc.)  Waste and waste water discharge	Land/soil gain/loss (e.g., land development, loss of agricultural land to competing uses, erosion)  Land/soil quality (erosion, desertification, salination, alkalization, ambient concentration of soil pollutants)	Land use regulation and zoning  Conservation of soils (e.g., afforestation, desertification control, use of environmentally sound production methods)	Inventory of soil/land (including use and tenure, characteristics and topographic conditions)  Inventory of vulnerable areas (disaster-prone areas, wetlands)
		Terrestrial ecosystems (e.g., changes in energy, material and nutrient flows, system productivity, species growth and diversity)	Waste disposal (including recycling) and pollution monitoring and control	Emission inventory (types and sources) of solids and liquid wastes and soil pollutants

Appendix 2 (continued)

Environmental Component	Social and Economic Activity	Environmental Impact of Activities	Response to Impact	Inventories, Stocks and Background Conditions
b. Sub-surface	<p>Mining and treatment of metallic and non-metallic minerals</p> <p>Extraction of energy resources (fossil fuels, geothermal and nuclear)</p> <p>Discharges (dusts and air pollutants, acid drainings, tailings, liquid wastes radioactive waste disposal)</p>	<p>Depletion/increase of mineral (including energy) reserves</p> <p>Land disturbance (e.g., open pits, waste disposal)</p> <p>Ambient concentrations of air and water pollutants</p>	<p>Reclamation and rehabilitation of land</p> <p>Conservation of land and ecosystems (e.g., mining regulations and control, protected areas)</p> <p>Recycling, substitution of mineral resources</p>	<p>Inventory of mineral resources (reserves of metallic and non-metallic minerals)</p> <p>Inventory of ecosystems</p> <p>Emission inventory (types and sources of discharges related to mining)</p>

## Appendix 2 (continued)

Environmental Component	Social and Economic Activity	Environmental Impact of Activities	Response to Impact	Inventories, Stocks and Background Conditions
		Human health and welfare impacts (e.g., mining accidents, contamination of mine workers, productivity/cost changes in mining operations)	Pollution control and monitoring	Land use and characteristics (land-use categories, vulnerable and protected areas, topographic and geologic characteristics)
			Health protection (e.g., for mining operations)	Economic factors affecting demand and supply of mineral resources (price/cost, production and consumption patterns, demographic factors)

Appendix 2 (continued)

Environmental Component	Social and Economic Activity	Environmental Impact of Activities	Response to Impact	Inventories, Stocks and Background Conditions
6. HUMAN SETTLEMENTS	Population growth and migration	Urban sprawl and concentration (population density and concentration)	Housing programs (e.g., low-cost housing, rehabilitation and upgrading, finance, building codes and regulations, slum clearance)	Inventory of buildings and infrastructure
	Construction (residential, non-residential)	Housing shortage and occupancy, access to utilities and community services	Land policies and control (zoning, resettlement and land development)	Inventory of hazardous industries, workplaces and activities
	Utilities (energy and water supply)	Marginal housing (slum and squatter settlements, decline of inner cities, sub-standard housing)	Self-help housing and community development programmes	Emission inventory (types, sources of pollutants in settlements)
	Transportation (public, private)	Ambient concentrations of waste and pollutants; noise levels and exposure	Monitoring and quality control of working environment	Land use (pattern, land tenure and characteristics)

## Appendix 2 (continued)

Environmental Component	Social and Economic Activity	Environmental Impact of Activities	Response to Impact	Inventories, Stocks and Background Conditions
	Land use in settlements (residential, industrial, commercial, transportation and other infrastructure)	Biological and ecological impacts (especially from urban sprawl and infrastructure development)		Economic factors affecting human settlements (demographic, industrialisation, informal sector, cost/prices, income distribution)

## Appendix 2 (continued)

## Example No. 2

Environmental Component	Social and Economic Activity (pressure/driving force)	Environmental Impact of Activities (part of the state)	Response to Impact (response)	Inventories, Stocks and Background Conditions (part of the state)
1. AIR/CLIMATE	Emissions of CO <sub>2</sub> , SO <sub>2</sub> and NO <sub>2</sub>	Ambient concentrations of CO <sub>2</sub> , SO <sub>2</sub> and NO <sub>2</sub> , O <sub>3</sub> in urban areas	Expenditure on air pollution abatement	Weather and climate conditions
	Consumption of ozone depleting substances	Air quality index	Reduction in consumption of substances and emissions	
	Land use change	Area affected by soil erosion	Protected area as % of total land area	
2. LAND/SOIL	Livestock per km <sup>2</sup> of arid and semi-arid lands	Land affected by desertification		Arable land per capita
	Use of fertilizers	Area affected by salinization and water logging		
	Use of agricultural pesticides			

## Appendix 2 (continued)

Environmental Component	Social and Economic Activity (pressure/driving force)	Environmental Impact of Activities (part of the state)	Response to Impact (response)	Inventories, Stocks and Background Conditions (part of the state)
3. WATER				
a. Fresh water resources	Industrial, agricultural and municipal discharges directly into freshwater bodies	Concentration of lead, cadmium, mercury, and pesticides in fresh water bodies	Waster water treatment, total and by type of treatment (% of population served)	Groundwater reserves
	Annual withdrawals of ground and surface water	Concentration of fecal coliform in fresh water bodies	Access to safe drinking water (% of population served)	
	Domestic consumption of water per capita	Acidification of fresh water bodies		
	Industrial, agricultural water use per GDP	BOD and COD in fresh water bodies Water quality index by fresh water bodies		

Appendix 2 (continued)

Environmental Component	Social and Economic Activity (pressure/driving force)	Environmental Impact of Activities (part of the state)	Response to Impact (response)	Inventories, Stocks and Background Conditions (part of the state)
b. Marine water resources	Industrial, agricultural and municipal discharges directly into marine water bodies  Discharges of oil into coastal waters	Deviation in stock from minimum sustainable yield of marine species  Loading of N and P in coastal waters		
4. OTHER NATURAL RESOURCES				
a. Biological resources	Annual roundwood production  Fuelwood consumption per capita  Catches of marine species	Deforestation rate  Threatened, extinct species	Reforestation rate  Protected forest area as % of total area	Forest inventory  Fauna and flora inventory  Fish stocks

## Appendix 2 (continued)

Environmental Component	Social and Economic Activity (pressure/driving force)	Environmental Impact of Activities (part of the state)	Response to Impact (response)	Inventories, Stocks and Background Conditions (part of the state)
b. Mineral (incl. energy) resources	Annual energy consumption per capita	Depletion of mineral resources (% of proven reserves)		Proven mineral reserves
5. WASTE	Extraction of other mineral resources	Lifetime of proven reserves		Proven energy reserves
	Municipal waste disposal	Area of land contaminated by toxic waste	Expenditure on waste collection treatment	
	Generation of hazardous waste		Waste recycling	
	Imports and exports of hazardous wastes			
6. HUMAN SETTLEMENTS	Rate of growth of urban population	Area of population in marginal settlements	Expenditure on low-cost housing	Stock of shelter and infrastructure
	% of population in urban areas	Shelter index		
	Motor vehicles in use per 1,000 inhabitants	% of population with sanitary services		

## CONVERTING PRIMARY DATA INTO INFORMATION: A METHODOLOGY FOR HANDLING LARGE DATA SETS

Problems relating to the quality of air and water have received the most attention in this Handbook. In Chapters 4 and 5, the construction and operation of systems to monitor these two media were discussed in some detail. The huge amounts of data obtained through monitoring, coupled with the construction of emission inventories and sample surveys, are the core of any national program. Unfortunately, these primary statistics cannot be easily understood by government officials or the general public. This appendix describes a simple methodology to transform the raw data into a more useful type of information.

Environmental indicators (EIs) are an essential part of the effort to summarize the results of a monitoring program. However, the methods of constructing these indicators, the forms of presentation, and the procedures for handling the primary data are equally important. A flaw in statistical procedures can jeopardize the credibility of the entire program. Similarly, failure to produce a simple and easily comprehensible set of indicators will lead to erroneous policy decisions and dwindling public support.

The methodology presented here is best suited for the assessment of large data sets. It allows analysts to condense a large body of statistics into summary measures while retaining the sensitivity of the original data to ascertain trends. The discussion draws mainly on examples referring to air quality, but the same techniques can be used in many other applications. Other environmental topics to which this methodology can be applied are large data sets referring to water quality and contaminated land.

***Data rationalization.*** The job of statisticians is to find some way to summarize the primary data gathered at monitoring stations. Such a process, which is often referred to as data rationalization, must satisfy

## Appendix 3 (continued)

at least two criteria. First, rationalization cannot result in any significant loss in data representativeness. Second, the information or indicators to be developed must be in a form that allows easy comparison with internationally accepted standards.

Before the process of data rationalization can begin, a considerable amount of preparatory work must be done. Decisions are needed on each of the following aspects:

- (i) identification of specific types of indicators that will satisfy the above criteria and still be easily understood by policy makers and the general public, and
- (ii) agreement on a suitable form of presentation that can accurately represent both current conditions and longer term trends in air quality in cities and provinces.

Some examples of pollutants that may be chosen for an initial assessment of air quality in urban areas in a developing country are carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>), suspended particulate matter (SPM), and sulfur dioxide (SO<sub>2</sub>). A similar set of indicators for water quality could consist of biological oxygen demand (BOD), chemical oxygen demand (COD), and so on. More generally, different combinations of pollutants are singled out when evaluating specific problems such as the effects of urban traffic on air quality, the quality of groundwater in a major catchment area, the air in residential zones, and so on. A number of these pollutants, or parameters, are discussed in Chapters 4 and 5 (see the sections Air Parameters and Water Parameters, respectively).

The form in which the indicators are presented is especially important for the users. Sometimes, statisticians choose to develop an index of pollutants, but the approach recommended here is to base the construction of indicators on actual physical and chemical measurements (that is, monitoring data). The advantages of this approach are that the indicators can be easily related to health and ecological effects and are derived from information that is scientifically credible. Such measures

## Appendix 3 (continued)

are also more easily understood by the public and nontechnical decision makers than indexes or other relatively complicated statistical expressions.<sup>1</sup>

**Presentation of box plots.** In this example, a hypothetical set of monitoring data on air quality is assumed to exist. This large body of data will be summarized in terms of a simplified representation of the frequency distribution for each indicator. Data averages are also calculated for various time periods, which depend on two factors: (i) the international standards against which the results are judged, and (ii) the type of health effect (acute or chronic) that each pollutant may produce. Short time periods (1 hour, 8 hours, or 24 hours) can be used to assess acute health effects, while longer time periods (for example, an annual average) refer to chronic health effects. Finally, ecological effects are judged in terms of both short and long time periods (for example, 8 hours and 24 hours), depending on the specific pollutant.

Table A3 suggests several time periods and averages that can be used to gauge health and ecological effects. These measures are based on international guidelines for air quality developed by the World Health Organization (WHO).<sup>2</sup> The guidelines were developed for Europe, but current evidence suggests that they are applicable worldwide since there appears to be no significant difference in the effects of air pollution on human health and the environment in other geographic areas.

Indicators based on the maximum annual values recorded at multiple monitoring sites are the preferred means of assessing trends in pollutant concentrations. These measures, which are also known as extreme value statistics, are thought to be more sensitive to variations

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<sup>1</sup> Indicators that are directly derived from primary data also have drawbacks. One is that a different measure must be constructed for each pollutant. The information obtained from monitoring stations is also site-specific and subject to temporal and meteorological variations.

<sup>2</sup> The WHO guidelines indicate thresholds for human exposure that should result in no adverse effects. For most pollutants, the guidelines also include a margin of safety based on the confidence of the dose-response relationship. See WHO (2000a).

## Appendix 3 (continued)

in air quality than other formulations such as a composite average calculated for a number of monitoring sites. Extreme value statistics can also be used for an evaluation of acute health effects. A drawback is that short-term meteorological variations and site-specific factors can distort trends based on extreme value statistics.<sup>3</sup> To account for this characteristic, the specific indicators proposed in Table A3 combine both extreme value statistics and average statistics of multiple sites. The combination of measures reduces the effects of data variability and makes the analysis of trends more reliable.

Presentation of statistics based on primary data for multiple sites will usually include monitoring results from stations located both inside and outside urban areas. To ensure that trends are being assessed across comparable locations, several broad-site categories should first be identified. In the case of air quality, these categories could include

- (i) urban, traffic-dominated (or commercial) sites,
- (ii) urban residential sites, and
- (iii) rural sites.<sup>4</sup>

After completing this preparatory work, the statistician can turn his attention to the task of data presentation. Primary data for each year for each selected indicator and all monitoring stations in a given region and site category is presented in the form of a simplified frequency distribution function or box-plot diagram. Figure A3.1 gives a hypothetical example for CO levels recorded by sites in an urban traffic zone. The simplified distribution shows only a sample of percentile values: in this

<sup>3</sup> The severity of meteorological conditions can vary from year to year, causing large fluctuations in the maximum value in each year recorded at each site. However, when the distribution function is constructed from data for a large number of monitoring sites, the influence of extreme values for individual sites is significantly reduced.

<sup>4</sup> Other categories could be considered when evaluating different issues relating to the quality of air or water.

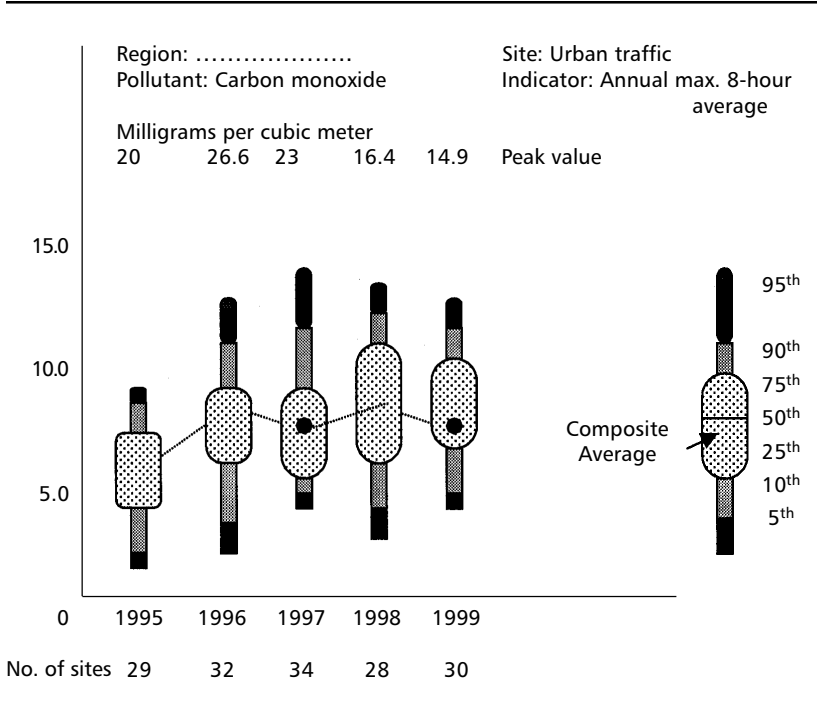
## Appendix 3 (continued)

**Table A3: Appropriate Time Periods for Presentation of Indicators Relevant to Acute and Chronic Effects and Ecological Effects**

Pollutant	Unit	Acute Health Effects	Chronic Health Effects	Ecological Effects
Carbon monoxide	mg/m <sup>3</sup>	Annual max. 1-hour average Annual max. 8-hour running average	No chronic health effects	No ecological effects
Nitrogen dioxide	mg/m <sup>3</sup>	Annual max. 1-hour Annual max. 24-hour	Annual average	Annual max. 4-hour running average Annual max. 24-hour Annual average
Particulate matter	mg/m <sup>3</sup>	Annual max. 24-hour	Annual average	No ecological effects
Sulfur dioxide	mg/m <sup>3</sup>	Annual max. 1-hour Annual max. 24-hour	Annual average	Annual max. 24-hour Annual average

Source: OECD (1999c).

Figure A3.1: A Box-Plot Diagram for Carbon Monoxide



case, the 5th, 10th, 25th, 50th (median or composite average), 75th, 90th, and 95th values. The highest reported value is given in numeric form at the top of the box-plot diagram and the number of monitoring sites is given below the simplified frequency distribution for each year. Such diagrams can be generated for almost any combination of region, site category, and pollutant indicator.

Once the data is displayed in this form, interpretation is straightforward. The hypothetical trends in Figure A3.1 show a modest increase in levels of CO between 1995 and 1999, with some annual variability. Concentrations at the most polluted traffic sites declined slightly in the most recent years. However, levels of CO at moderately polluted

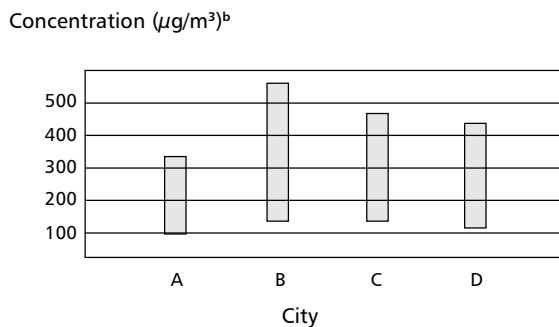
## Appendix 3 (continued)

sites (for example, those between the 25th and 75th percentiles) have gradually risen over time. There is also considerable annual variability.

**Presentation of peak statistics.** The box-plot diagrams described above can be supplemented by constructing peak-statistics bar charts. These figures are used to describe levels of air pollution in cities, or water pollution along stretches of a specific waterway. A bar chart shows the highest and lowest annual maximum values and the composite average for each indicator.

An example referring to the maximum one-hour concentration for levels of nitrogen dioxide is found in Figure A3.2. The chart reports the highest and lowest values, along with the composite average, recorded by monitoring stations in each of four cities. When presenting statistics on the quality of urban air, bar charts must be constructed for each pollutant indicator. Generally, the cities included in these charts are all those with populations greater than one million. For countries with fewer

**Figure A3.2: A Bar Chart for Urban Peak Statistics:  
Concentrations of Nitrogen Dioxide in Major Cities<sup>a</sup>**



<sup>a</sup> Figures refer to annual 1-hour maximums.

<sup>b</sup> WHO air quality guideline is  $200 \mu\text{g}/\text{m}^3$ .

## Appendix 3 (continued)

than three cities of one million residents, statistics for at least the three largest cities should be presented.

The type of bar chart described here does not necessarily contain the same data as the box-plot diagram discussed in the preceding section. Ideally, box-plot diagrams provide a means of tracking trends over several years while peak-statistic bar charts refer to the concentration of pollutants during a single year. The time periods chosen for determining averages should—to the extent possible—reflect WHO guidelines in both cases.

***Limitations and future development.*** Many developing countries may lack the monitoring facilities and data-processing capabilities that are desired if the methodology is to meet rigorous statistical standards. For example, the minimum number of monitoring sites recommended to generate box-plot diagrams showing selected percentiles is around 20. The inclusion of data from a large number of sites reduces the impact of year-to-year variability. In fact, the number of monitoring sites should probably be close to 50 to obtain consistent annual trends. Trends observed on the basis of only a small number of sites will almost certainly be somewhat irregular. This shortcoming will be common to most developing countries at early stages in the environment program, but it should not prevent the development of indicators or their dissemination to government officials and the general public. The long-run goal should be to construct a monitoring network that will yield statistically reliable results. In the meantime, the assessment of each indicator should be extremely cautious and qualified.

Annual changes in meteorological conditions may give rise to correspondingly large variations in pollution concentrations and these effects will be exacerbated by a less-than-sufficient network of monitoring stations. One way to account for this problem would be to normalize the data with respect to an “average” meteorological year. Normalization can improve the decision-making content of the information, but it may also diminish public confidence in the environmental data. Thus, it should be treated purely as an interim measure.

## Appendix 3 (continued)

Finally, statisticians in developing countries will encounter difficulties when attempting to evaluate trends based on only a few years of observations. The use of relatively short time series for most box-plot diagrams is unavoidable since data for more than 2-3 years will not be available for most monitoring sites. In the future, the availability of additional years of data will significantly improve the reliability of trend analysis.