Urban Management Program

A Review of Environmental Health Impacts in Developing Country Cities

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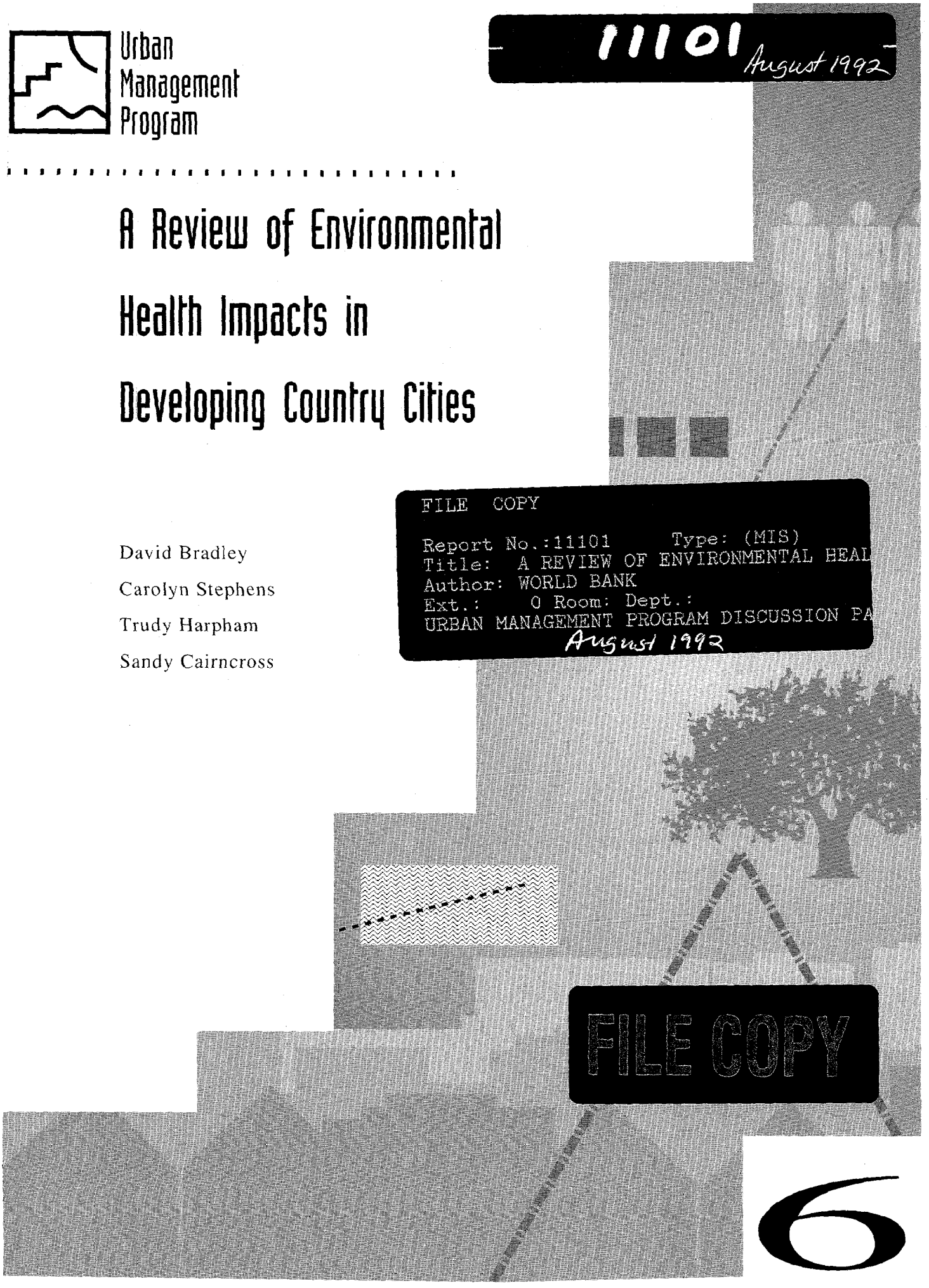

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URBAN MANAGEMENT PROGRAM DISCUSSION PAPER

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Urban Management and The Environment

A Review of Environmental Health Impacts in Developing Country Cities

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The Urban Management Program (UMP) represents a major approach by the United Nations family of organizations, together with external support agencies (ESAs), to strengthen the contribution that cities and towns in developing countries make towards economic growth, social development, and the alleviation of poverty. The program seeks to develop and promote appropriate policies and tools for municipal finance and administration, land management, infrastructure management, and evnironmental management. Through a capacity building component, the UMP plans to establish an effective partnership with national, regional, and global networks and ESAs in applied research, dissemination of information, and experiences of best practices and promising options.

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"Man should not try to conform to the environment created by social and technological innovations; he should instead design environments really adapted to his nature."

Rene Dubos

FOREWORD

This paper has been prepared for the Urban Management and Environment component of the joint UNDP/World Bank/UNCHS Urban Management Program (UMP). The UMP represents a major approach by the UN family of organizations, together with external support agencies (ESAs), to strengthen the contribution that cities and towns in developing countries make toward economic growth, social development, and the alleviation of poverty. In addition to its environmental focus, the program seeks to develop and promote appropriate policies and tools for land management, infrastructure development, municipal finance and administration, and poverty reduction. Through a capacity building component, the UMP plans to establish an effective partnership with national, regional, and global networks and ESAs in applied research, dissemination of information, and experiences of best practices and promising solutions.

This research review is part of a series which will be used, in combination with background studies, discussion papers, and case studies, to develop an overall strategic framework paper on Strategic Options for Urban Environment Management. Additional research reports are being prepared on: (i) the local management of wastes from small-scale and cottage industries; (ii) the economic spillover effects of urban environmental problems; (iii) urban environmental data collection; and (iv) the application of remote sensing and geographic information systems to urban environmental planning. Other topics in the discussion paper series will cover urban waste management and pollution control, regulatory and economic instruments for pollution control, land degradation, and the urban environmental planning and management process. Each is designed to provide information on key urban developmental-environmental linkages and/or suggest elements of an environmental management strategy for cities in the developing world. Finally, case studies on priority urban environmental problems are being prepared for São Paulo, Katowice, Tunis, Accra, Jakarta, Tianjin, and the Singrauli region of India; all of these will be inputs to the final paper on strategic options.

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EXECUTIVE SUMMARY

Background

1. The World Bank is currently assessing the relative health impacts of physical environmental problems in urban areas of developing countries in order better to guide its urban policy and investment decisions. As a contribution, this report reviews and summarizes available literature on health in the urban areas of developing countries. It discusses associations between health and problems of the material environment. The objectives of the report are:

- to produce a classification of environmental variables relevant to urban health in developing countries;

1.1

- to propose an analytical framework for relating environmental variables to health;

- to review intra-urban differentials in mortality, morbidity and causes of death in developing countries, with particular reference to vulnerable groups;

- to review literature that attempts to link causally urban environmental conditions to health in developing countries; and

- to propose future related research.

Review

2. Over 100 studies are reviewed in this paper to identify emerging patterns and gaps in the environmental health field. Descriptive studies that examine intra-urban differentials in mortality point to the link between poverty and mortality, but without reference to intermediate variables. The larger number of studies that examine intra-urban differentials in morbidity tend to focus on diseases transmitted through the gastrointestinal tract. Studies on intra-urban differentials in respiratory, skinborne and arthropod-borne diseases remain rare. Evidence of intra-urban differentials in nutritional status, however, is plentiful. Poorer groups are at distinct disadvantage.

3. An analysis of causes of death in urban areas presents a picture of urban populations suffering the "worst of both worlds"—a mixture of deaths from infectious and chronic diseases. Data tend to come from countries where both registration of death and urbanization are more advanced.

4. The group most commonly studied is children. An abundance of studies demonstrate a high prevalence of diarrhoea and helminth (parasitic intestinal worm) infections in children of slums, shanty towns and squatter settlements, yet there is a dearth of studies on respiratory infections. The elderly and teenagers are also vulnerable groups, but are neglected in research.

5. Causal studies relating urban environmental conditions and mortality should be interpreted with caution—in some, association of environment and mortality are derived from demographic data, while other studies limit their investigation to a particular age or socioeconomic group.

6. There are several studies linking infant mortality to water quality. Access to an "individual" water supply is also an important variable. The interaction of behavioral factors is noted, including the importance of maternal education. The literature on links between urban environment and mortality is biased toward infant deaths. On adult mortality in urban areas, data indicate that the interaction of psychosocial variables and adult deaths produces a pattern largely idiosyncratic to that city and that people, at that time.

7. The studies analyzing morbidity are more numerous than those tackling causes of mortality in urban areas, but they do not show a comprehensive or uniform pattern of linkages between urban environment and health. Analysis of infant morbidity and its relation to water accessibility, water quality, and sanitation shows some of the strongest associations of environmental variables and disease outcomes. Many studies point to the complex synergism of environmental and social risk factors for disease, and there is much evidence that health outcomes in the urban environment derive ultimately from the socioeconomic more than the physical environment. Poverty remains the most significant predictor of urban morbidity and mortality.

A Hypothetical Urban Health Profile

8. Notwithstanding the obvious gaps in the information available and the uniqueness of each city's health status, the review does suggest a stylized urban health profile that provides a useful point of departure for analyzing health conditions in a specific city:

- In contrast to higher income urban dwellers and some rural populations, the urban poor have a lower life expectancy at birth and a higher infant mortality rate.

- The relationship of infant and child mortality to the quality of and access to water and sanitation is significant—children from households using public standposts and cesspools are several times more likely to die of diarrhea than those with in-house piped water and sewerage.

- Urban poor households sometimes have worse nutritional status than rural households, contributing to ill-health related to nutrition.

- Female children in slums are further disadvantaged compared with males in terms of differential nutrition, health care, and mortality.

- When a child from a slum is old enough to move independently about the city, he or she may become increasingly exposed to death associated with violent features of modem urban environments, for example, motor vehicle accidents (5–14 years) and homicides (15–19 years).

- In some cities, for youths and young adults, mortality differentials may be due to communicable disease and violence in males, and obstetric causes for females.

- From 15 years onward, trauma and chronic diseases play a substantial role in mortality and morbidity; one particular problem may be the occupational exposure associated with informal, small scale and cottage industry, and exposure in the home.

9. These hypotheses are open to test: the main challenge is to collect better mortality data, especially regarding the likely causes of death, from cities in the developing world.

Recommended Research

10. This review found few good studies available on intra-urban differentials in morbidity and mortality and linkages to environmental conditions, thus emphasizing the need for increased research in this area. Several promising research approaches are recommended:

1. **Analysis of Demographic and Health Surveys (DHS)**: These surveys exist for several countries with sufficiently large urban subsamples to justify further examination of the data for the purpose of intra-urban analysis. Secondary analysis of these large population-based surveys, whose quality has been validated, is recommended as an effective and efficient way of producing more information on the intra-urban differential in health. Given the nature of DHS, these differentials can then be tested for associations with environmental variables such as housing quality, water, and availability of sanitation.

2. **Linkage with Forthcoming Surveys**: Another efficient way to gain more information on the linkages between environmental problems and the health of vulnerable groups is to ensure key questions are included in forthcoming surveys to be undertaken for a variety of reasons.

3. **Increasing the Utility of Routine Surveillance Data**: The statistics normally collected at health facilities could be put to much greater use. Data on the homes of patients, which are rarely filed in a logical form, could be used to assist further data analysis. If death certificates were sorted by postal code this would open up a new area for spatial analysis of this data. Other routinely collected data could also yield better information if records had some simple residential information. The introduction of such a planned use of data could be explored in a medium-sized city to determine the feasibility of the effort.

4. **Informal Occupational Hazards**: Understanding of occupational hazards at the community level in developing countries is minimal. This is particularly the case for small-scale industries and the informal sector. Field studies are needed to assess the scale and the nature of health risks in developing countries. An initial study in one or two cities should be supported to provide an initial estimate, to develop a methodology, and to assess the difficulties of such work.

5. **Urban Air Pollution**: Urban air pollution at both area and household levels requires further understanding. Analysis of air sampling data and studies of domestic air pollution in relation to respiratory infections have recently begun. This area needs more resources for research.

6. **A Possible Model**: To provide an analytical framework, a "model city" is postulated. The model assumes a city of one million people in the developing world, with four social/economic/environmental levels, two sexes, and six age groups. For each of these 48 cells, and on the basis of any available data and informed judgment, estimates are made of the proportion of the total population, the specific death rate, and so the distribution of deaths. For each cell, causes of death are allocated and finally related to environmental changes. The model is described in the annex herein together with the hypothetical data. The attempt to construct a model revealed the inadequacy of existing data sets for developing such a model. Field research is recommended to generate the information needed for building other urban environmental health profiles in one or two developing country cities.

Proposed Follow-up

11. Of the approaches suggested above, detailed research proposals have been prepared for carrying out an analysis of the DHS surveys for three or four countries, and for constructing the urban environmental health profile model for two cities: Accra (Ghana) and São Paulo (Brazil). These activities will be carried out in partnership with in-country researchers, and will be funded by The Natural Resources and Environment Division of the Overseas Development Administration of the United Kingdom.

Contents

Tables

I. CLASSIFICATIONS OF HEALTH AND ENVIRONMENT: TOWARD A CONVERGENT TAXONOMY

1.1 Our environment is infinitely complex, and the diseases of man are numerous. To reduce such complexity to manageable form, components of both environment and health must be grouped into categories. Yet physicians and those concerned with the environment have their own distinct approaches to such a classifications. Many approaches have been tried by each group, and these have often been far from mutually compatible. This section discusses the categorization of health and the physical/biological environment, especially the health problems of urbanization. It also moves toward a taxonomy of disease and of environment. Among the extremely complex determinants of urban health, we emphasize four:

- the physical/biological environment;
- disposable income;
- behavior;
- and the availability of quality health care services.

1.2 The effects of these four factors are so closely intertwined that it is misleading to consider them in isolation. In particular, the impact of the physical environment on health is mediated largely by human behavior, and the effects of changing income on both these is very important. Our review and analysis is mainly limited to the physical and biological aspect of the total environment.

Categorization of Disease

1.3 Most systems for disease classification used in official statistics are derived from the *International Classification of Diseases* (ICD), prepared by the World Health Organization (WHO). Because this classification is so detailed, many countries use either a selected list of common items from the ICD, lumping everything else as "other," or only the broader categories. Few of the world's medical practitioners and even fewer health workers have seen the ICD, so errors of categorization are likely to be massive. Nevertheless, the ICD provides the recognized starting point for disease classification.

1.4 Disease classifications are primarily anatomical. Illnesses are grouped by the organ system affected. This reflects the history of medicine and the need to classify illness before the causes of disease were understood. It also reflects medical specialties that tend to be linked to organ systems. Typical examples can be found in the chapter headings of the elaborate *Oxford Textbook of Medicine* and of the more basic *Davidson's Textbook of Medicine* and *Anderson's Pathology*. A reader will note illogical omissions from *The Oxford Textbook of Medicine* because some diseases are traditionally considered surgical. More illuminating are pediatric texts, which often contain a comprehensive view of health and disease for infants and children.

1.5 Communicable diseases are the major exception to an organ system of classification. These have been largely removed from the preceding system, placed in a separate classification, and subdivided on the basis of the biology of the causative agent. Diseases caused by viruses, bacteria, protozoa, and parasitic worms are classified into different subgroups. Microbiology and parasitology dominate the agent system of classification. Because the organ and agent systems exist side by side, and recognizing the fact that little training is given to health professionals on the logic or principles of classification, there is substantial inconsistency of reporting in the compilation of routine statistics, especially by primary health care workers. This is particularly true when only a few categories are permitted.

1.6 Thus abdominal pain and vomiting may be diagnosed as "gastroenteritis," which in fact may be caused by a range of viruses, bacteria, or bacterial toxins, or, much less frequently, to a non-microbial cause. The primary health care worker may record it under "gastrointestinal disease" or under "parasitic and infectious" disease. The first will lump gastrointestinal diseases with diseases of affluence, illnesses of uncertain relation to any socioeconomic variables toxic effects, etc. If in the record category of parasitic and infectious diseases, gastroenteritis joins an enormous bulk of diseases, particularly in the developing world.

1.7 Tuberculosis is another condition that may turn up at various places in a disease classification. Open, infective, pulmonary tuberculosis will usually appear in its own subcategory of infections, but it may often be misclassified with pulmonary diseases (indeed, it logically also belongs there). More often, intestinal tuberculosis will appear in the gastrointestinal disease category together with psoas abscess, while spinal tuberculosis (Pott's disease) will appear in reporting data under either neurological or bone diseases or diseases depending upon the main presenting signs and symptoms. Problems of this sort are typical of routinely reported data!

1.8 Disability is often more relevant than disease, but there is a limited correlation between a classification of disease and one of disability, though there is an international classification of impairments and disabilities. The medical classification of disability can be related to a classification of disability in terms of its economic effects, but these are culture-dependent.

Categorization of Environment

1.9 The definition of environment is generally socially constructed. If we ask a mountaineer, a sanitary inspector, and a conservationist what they mean by "the environment" we shall get very diverse answers. The biologist's definition of environment is probably the most logical and usable and consists of the world outside ourselves, that is to say the physical and natural environments. For present purposes this is probably sound, although the reader is likely to disagree. Note that "urbanization" is more than just construction and habitation of structures. Formally, everything other than the genome either is or bears the mark of the environment. Narrowing the scope of inquiry is a matter of convenience more than logic, so it is best to look widely at first.

A Relevant Taxonomy

1.10 What we seek here is an etiological classification of disease, particularly one that reflects environmental causes. To match it we also need a disease-oriented or, even better, a health-oriented, classification of environment. The discussion in Section III highlights the difficulty of such an endeavor because causation can be multiple, variable, hard to measure, and sometimes, simply, unknown. Without understanding something about symptomatic mechanisms, even good correlations between environment and disease are not useful to the planner. For example, a study of the Luo in Kenya showed that relocation to an urban area causes an almost immediate rise in the blood pressure of an adult male. Without knowing the mechanism—which in this case is believed to be related to an increase in the salt content of the diet—such information cannot benefit the urban planner.

1.11 In the case of water resource changes, it has been found that a taxonomy of communicable disease based on the environmental interventions most relevant to control rather than the biology of the agent has become well established and presumably useful (White, Bradley, and White 1972). This is relevant to some disease problems of urbanization, but we shall also attempt to apply similar principles to the classification of urban health problems.

1.12 We suggest that, for the purpose of urban planning as it affects health, a useful classification may be as set out in Table 1–1, which considers the environment strictly in relation to man. We do not consider this as an adequate view of the environment for other purposes, nor do we subscribe to the position that the environment's value is only in relation to man. Our aim here is to relate the environment of the city to human health. One primary analysis is of environment as a resource, as a hazard, and as ambience.

1.13 This has some use as a classification since it groups together matters requiring similar types of intervention. We suggest that environmental components may be categorized as:

- where the environment is providing a resource for urban inhabitants;
- where the environment is acting primarily as a hazard (from the health viewpoint);
- and where the environment outside the home forms the ambience to which man has to adapt.

1.14 The issues raised by each category differ: for resources, the practical questions concern availability, access, and cost; for hazards, issues involve the form of contact with people, prevention, containment, or failing that, amelioration; for ambience which cannot be changed, the issues concern protection (shelter)—from extremes of temperature and rainfall—and adaptation.

Table 1–1. Proposed Environmental Classification for Health Analysis

Environment as:

Resource — availability, access, cost:

* Water
* Health care
* Food
* Cooking facilities
* Shelter

Hazard - route of entry, prevention, containment, amelioration:

* Pollution — inevitable (personal wastes)
  — partly inevitable (domestic, some industrial)
  — preventable (occupational, locational)
* Trauma
* Vectors

Ambience — protection, adaptation:

* Weather — temperature, humidity
  — surface water
* Other people
* Other animals

1.15 These broad categories are shown in Table 1–1 with the specific environmental components grouped under the appropriate heading. The qualities of each primary category may be modified by how it is perceived, by our ability to influence or modify the environment, and by the spatial scale over which we are thinking.

1.16 We now set out several other environmental classifications which are progressively more influenced by their relation to diseases. As the classifications become easier to relate to the cause of specific diseases, they become less satisfactory from an environmental viewpoint.

1.17 In the same way that most classifications of infectious disease are categorized by the biology of the agent rather than the relationship to the host, most environmental classifications are ordered by the structure of the physical world and its properties: air, water, soil, sunlight, temperature, and humidity. Such classifications can be found in many books on ecology, geography and "the environment."

1.18 One influential ecological text (Andrewartha and Birch 1955) took a more imaginative approach and classified the environment into:

a) weather (temperature, humidity, rainfall, surface water).

Table 1–2. An Environmental Taxonomy Related to Disease Patterns

Water-wastes complex	Other people
domestic water	crowding
excreta	organic pollution
drainage	trauma
surface water	inorganic pollution
water-related vectors	
solid wastes	Other organisms
solid waste-related vectors	domestic animals
rodents	stock
	vectors
Shelter and the built environment	
housing	Weather
cooking facilities	temperature
sanitary facilities	humidity
health care facilities	natural disasters
transport system	other extreme events
air pollution	
Food	
food supply	
food hygiene	
markets	
slaughterhouses	
food processing plants	

b) food (including food, drinking water and possibly cooking facilities).
c) a place to live (shelter, perhaps health care facilities).
d) organisms of the same kind (crowding and pollution).
e) other organisms of different kinds (predators and pathogens).

1.19 The reasons behind this classification had much to do with the then contemporary ecological polemics, but this categorization is valuable because it reflects the environment in relation to the organism under consideration. The Andrewartha and Birch approach is more helpful than others for urban environmental health purposes because it takes into consideration the effects of urban population densities (overcrowding) and population growth. However, a more relevant environmental grouping of items must also include the standard topics addressed in public health and environmental engineering, this is attempted in Table 1–2.

1.20 Table 1–3 presents a classification based on interventions related to the effects on disease. It is the closest example of an environmental classification to disease problems that we have, as reported in standard categories and in medical certification of the causes of death. It is clear that

Table 1–3. Environmental Determinants of Health Problems

I. Determinants of ingested health problems.
- 1. Domestic water supply
- 2. Sanitation—excreta disposal
- 3. Hygienic facilities (soap availability, privacy, etc.)
- 4. Food hygiene
- 5. Markets
- 6. Slaughterhouses
- 7. Cooking facilities
- 8. Fuel
- 9. Industrial pollutants

II. Determinants of other organisms and of the functioning of I.
- 1. Drainage
- 2. Surface water
- 3. Solid wastes

IIa. Consequences, especially of II, in the environment.
- 1. Rodents
- 2. Insect vectors
- 3. Nuisance insects
- 4. Intermediate host snails

III. Determinants of the inhaled health problems.
- 1. Crowding
- 2. Domestic air pollution: stoves
- 3. Community air pollution
- 4. Industrial air pollution
- 5. Transport related air pollution

IV. Proximal determinants of environmental stress.
- 1. Household temperature
- 2. Household humidity
- 3. Protection from rainfall
- 4. Protection of possessions
- 5. Transport facilities: vehicles and roads

V. Determinants of the bases of IV, III, II, I.
- 1. Weather

VI. Determinants of trauma and toxicity
- 1. Transportation systems
- 2. Availability of weapons
- 3. Industry—activities
- — pollution to air and water

VII. Determinants of nutritional state.
- 1. Foods: availability, access and cost

VIII. Other environmental health problems
- 1. Domestic animals

IX. Modifiers of the effects of the above
- 1. Health care facilities

each category is environmentally heterogeneous. An intervention-oriented classification of environment cannot be readily linked to any routinely available disease reporting system.

Causes of Death

1.21 The classification of causes of death will have to be very simple. If we subdivide the causes of death (or morbidity) to a great degree (even greater than the components of the ICD since the same condition may have different etiologies), then it is possible to relate some to environmental variables. The clearest linkages are to rare events. We can firmly link mesothelioma, a form of cancer, to asbestos, but it is a very rare tumor. For more common diseases, the relationships are less clear, and the literature we reviewed does not allow for accurate estimates. It is possible to make a list of diseases and possible environmental influences without adding much to the general knowledge available.

1.22 Table 1–4 relates a more orthodox list to types of activity predominantly needed, and a list of urban diseases that is of the level likely to be available is in Table 1–5.

Table 1–4. A Summary of Urban Environmental Factors and Potential Areas of Action

Factor	Action
Water	Provision and control/education
Sanitation	Provision and control/education
Hygienic Behavior	Provision and control/education
Health care facilities	Provision and control/education
Immunization	Provision and programs control/education
Vector Control	Action/enforcement of legislation
Garbage collection	Provision/maintenance
Food hygiene	Enforcement of legislation
Occupational safety	Enforcement of legislation
Pollution control	Enforcement of legislation
Trauma reduction	Enforcement of legislation
Cooking stoves	Financing/provision/education
Shelter improvement	Financing/provision/education
Walls improved	Financing/provision/education
Crowding reduced	Financing/provision/education
Heating, light, noise	Financing/provision/education
Communication: roads, transport	Provision/maintenance
Nutritional provision	Finance/supply/education

Table 1–5. A Simple List of Major Urban Disease Categories*

- Diarrheal diseases
- Respiratory diseases
  - Acute respiratory infections
    - Pneumonia
  - Tuberculosis
  - Chronic respiratory disease
- Sexually-transmitted diseases
  - AIDS
- Other Infectious and Parasitic Diseases
  - Measles
  - Helminths
  - Other
- Gastrointestinal diseases
- Genito-urinary diseases
- Gynaecological diseases
- Obstetric deaths
- Perinatal deaths
- Cancer
- Cardio-vascular diseases
  - Rheumatic heart disease
- Cerebro-vascular diseases
- Trauma
  - Accidental
  - Occupational
  - Personal Violence
  - Traffic
- Mental and behavioral diseases
- Addictions
  - Alcoholism
  - Drug Addiction
- Malnutrition
- Skin diseases

* This is in no sense a model, but rather an illustration of the type of categories that are likely to be available, at best, for routinely collected data.

II. A REVIEW OF INTRA-URBAN DIFFERENTIALS IN MORTALITY, MORBIDITY, AND CAUSES OF DEATH

2.1 The number of studies shedding light on intra-urban differentials in health in developing countries has substantially increased during the last five years. This section of the report reviews the published literature to find patterns of intra-urban differentials in mortality, morbidity and causes of death. Studies focusing on particularly vulnerable groups (for example, slum children or pregnant women in slums) are also reviewed.

2.2 This review focuses on epidemiological and demographic studies in urban communities. It therefore excludes two large bodies of research literature, which when carefully interpreted can offer a wealth of insight into the health impacts of environmental problems in urban areas. First, there are demographic and epidemiological studies from rural areas that relate to mainly rural populations, such as the classic United States studies of the 1920s, showing how a lack of sanitation promoted hookworm, *Ascaris*, and *Trichuris* infection. The conclusions can be judiciously extrapolated to urban settings.

2.3 Second, there are studies of environmental microbiology and disease vector biology, many of which demonstrate how common urban environmental problems can promote specific diseases. For example, studies of mosquito breeding-sites can tell us whether blocked drains, water storage vessels, or defective septic tanks are responsible for vectorborne disease in a given urban setting.

2.4 Compared with such rural or ecological studies, demographic and epidemiological research provides evidence for the health impacts of environmental problems which is in some senses more direct. This evidence nevertheless requires careful interpretation. As in any science, some studies are of poorer quality (and their findings less trustworthy) than others. Moreover, a statistical correlation between an environmental factor and an increased risk of death or disease does not prove that one causes the other. For example, people who do not own a television are more likely to be malnourished than those who do, but no one would argue from this that a television would improve their nutritional status.

Intra-urban Differentials in Mortality

2.5 Table 2–1 presents some of the studies that demonstrate the importance of disaggregating average city health statistics. Mortality rates are associated with socioeconomic status or geographical area, which is a proxy for socioeconomic status in the case of slums, shanty towns, and squatter settlements. Caution is needed in comparing results of studies of mortality rates because the methods of information-gathering differ (for example, health facility-based data collection or community based household survey data). Many of the studies are from Brazil where death registration is more complete than in some African or Asian countries. In addition, urbanization is at an advanced stage in Brazil and has therefore attracted the attention of many researchers. Table 2–1 also includes the famous studies that contributed to the *Black Report*, which firmly established the link between mortality rates and socioeconomic status within the United Kingdom. The picture

Table 2–1. Summary of Literature on Intra-urban Differentials in Mortality in Developing Countries

Author(s)	Year	Location	Findings/Comments
Anson	1988	Israel	In 72 urban centres Anson found that mortality was most closely related to availability of material resources. Car ownership, employment and education were the most important variables.Overcrowding was the least important indicator of mortality levels. The author attributes this to the existence of public housing in Israel, with associated rent subsidy and low interest mortgages.
Basta	1977	Manila, Phillipines	IMR for Manila was 76/1,000 while it was 210/1,000 in Tondo, a squatter area. Neonatal mortality for Manila was 40/1,000 while it was 105/1,000 for Tondo.
Bianco	1983	Buenos Aires, Argentina	Mortality due to TB was 3 times higher in the aperipheral areas than in the city.
Breihl et al	1983	Quito, Ecuador	IMR in upper class districts 5/1,000. For manual workers in squatter settlements it was 129/1,000.
Carstairs	1981	37 municipal wards in Glasgow, 23 in Edinburgh, Scotland	Strong evidence of greater mortality and morbidity in areas of greater deprivation (except for perinatal and infant deaths).
de Carvalho and Wood	1978	Rio de Janeiro, São Paulo, and Belo Horizonte, Brazil	Life expectancy at birth in Rio was 54 years in lowest income group and 62 years in higher income group.
Cassim et al	1982	Colombo, Sri Lanka	IMR in squatter settlements significantly higher than in better-off districts.
Fox et al	1984	36 geographic clusters of wards in England and Wales	Pattern of low mortality in high-status areas and high mortality in low-status areas.
Guimaraes and Fischmann	1985	Porto Alegre, Brazil	IMR in squatter settlements was 75.5/1,000 compared to 25/1,000 in non-squatter areas.
IBGE	1986	Urban Brazil (general)	In Northeast Brazil, the infant mortality rates in poorest families and in children of least educated mothers were respectively 8.3 and 7.2 times those for the richest and for the best educated mothers. Corresponding ratios in Southeast Brazil were 3.3. and 2.6 respectively. There is also an attempt to relate IMR to water supply and sanitation, but no effort is made to control for confounding by socioeconomic status.
McCord and Freeman	1990	Harlem, United States of America	Mortality rate in Harlem was highest in New York and 50 percent higher than that of all US blacks. The authors conclude that Harlem has a high enough mortality rates to justify natural-disaster area status. Survival analysis showed men in Harlem were less likely to reach age 65 than men in Bangladesh.

Table 2–1. (continued)

Author(s)	Year	Location	Findings/Comments
PAHO	1988	Urban Brazil (general)	Found a mortality excess of male: female of 133 male deaths for each 100 female deaths.
Rummel	1987	São Paulo, Brazil	Overall mortality rates were higher for blue collar workers than white collar workers and still higher for the unemployed.
Thunhurst	1985	29 wards in Sheffield, United Kingdom	Clear correlation between "areas of poverty" and mortality for men and women. For men, life expectancy over eight years greater in most affluent wards compared to most deprived.
Timaeus and Hill	1985	Andana, Turkey	Increased infant and child mortality was found in households where overall dwelling quality (as measured by building material) was poor.
Townsend et al	1986	755 wards in London, United Kingdom	Mortality rates in the most deprived wards nearly double that of the least deprived wards.
Victora et al	1986	Pelotas, Brazil	Perinatal mortality rate in families with less than 1 minimum salary per capita was 45/1,000. Where more than 10 minimum salaries per capita it was 13/1,000.
World Bank	1984	São Paulo, Brazil	IMR 42/1,000 in core areas, 175/1,000 in one of the peri-urban municipalities.

that emerges from this table links poverty and mortality but without reference to intermediate variables.

Intra-urban Differentials in Morbidity

2.6 In categorizing the available literature Table 2–2 uses the following morbidity groups:

Nutrition
Psychosocial diseases and trauma
Airborne infection
Skin and mucous membranes
Arthropod-borne
Gastrointestinal tract

2.7 A number of studies, ranging from Uganda and Ethiopia to Brazil and Panama, have established the greater prevalence of diarrhea and various helminths in environments with poor housing, water, and sanitation facilities. The question, "does higher socioeconomic status confer protection even if within a poor physical environment?" is not clearly answered. McCullough (1972) suggested that the answer is no, at least for roundworm. This question is worthy of further research.

Table 2–2. Summary of Literature on Intra-urban Differentials in Morbidity in Developing Countries

Author(s)	Year	Location	Findings/Comments
Morbidity group: nutrition			
Bogin and MacVean	1981	Guatemala City Guatemala	Stunting more prevalent among low socioeconomic stratum children than in high socioeconomic stratum; wasting was the same.
Datta Banik	1977	Delhi, India	Vitamin A, B and D deficiency and malnutrition higher in preschool children from slums compared to nonslums.
Franklin et al	1984	Kinshasa, Zaire	Children 6 months - 5 years. In old middle-class areas 24 percent were 90 percent height for age median. In new lower-class areas it was 42 percent.
Jansen et al	1977	Belo Horizonte, São Paulo, Brazil	Poorest dietary pattern amongst the lowest income group.
Mohan et al	1981	Bogotá, Colombia	Southern and peripheral areas of the city have much higher incidence of malnutrition than the rest of Bogota.
Monteiro et al	1986	São Paulo, Brazil	Malnutrition (Gomez I, II and III) was 33 percent in lowest socioeconomic stratum and 10 percent in upper stratum.
Popkin and Solon	1976	Urban, Philippines	Malnutrition and vitamin A deficiency higher in children of working mothers.
Victora et al	1987	Pelotas, Brazil	Weight gain in first year of life was 20 percent greater in upper class children than in lower class, irrespective of birth weight.
World Bank	1989	Porto Alegre, Brazil	A Pan American Health Organization survey found 15 percent of men and 24 percent of women were obese, with the prevalence particularly high for poorly educated women.
Morbidity group: psychosocial and trauma			
Klein et al	1985	Volta Redonda, Brazil	Prevalence of high blood pressure was much greater among the less educated than among the more educated.
Iyun	1989	Ibadan, Nigeria	Clinic-based data of 478 mental patients. Found that the bulk of patients with mental ill health were 16-35 years (67 percent) with age group 21-25 most affected (21 percent of cases). Males comprised 50.2 percent of cases, females 49.8 percent. Males suffer more from organic psychosis, alcoholism, drug abuse and neuroses. A higher proportion of females suffer from senile psychosis. Spatially, Iyun identified the low income, deteriorated housing core as a source of cases. Also the high income outer city area is a dominant source of cases. Mental stress in high income areas is associated with socioeconomic frustration. Traders and students comprise 24 percent and 23.6 percent of all patients suffering from mental ill health.
Mari	1987	São Paulo, Brazil	Psychiatric morbidity: The prevalence of minor psychiatric morbidity was 56 percent at Brasilandia, a poor slum area with a high proportion of migrants; 50 percent in Servidor, a community of civil servants; and 47 percent in Barra Funda, an area with a stable, though slum population. Women and low income families were more likely to be cases.

Table 2–2. (continued)

Author(s)	Year	Location	Findings/Comments
Sitthi-Amorn et al	1989	Bangkok, Thailand	Hypertension prevalence in over 30 year olds was 17.3 percent in Klong Toey slums and 14 percent for government apartment dwellers. Risk factors included age, duration of smoking, duration of alcohol intake, high body mass index and high cholesterol. The data suggested hypertension is a significant problem for low socioeconomic communities.
World Bank	1989	Brazil, various	Prevalence of alcoholism in adults ranges from 6 percent in Salvador to 13 percent in Riberao Preto and São Paulo. In Porto Alegre 18 percent of men and 2 percent of women drink alcohol daily. Uneducated men are three times more likely to drink than men with post secondary education.
Morbidity group: airborne infection			
Fischer and Hofmeister	1988	Cubatão, Brazil	A study on respiratory capacity of young children found that reductions in moderate and severe respiratory impairment between 1983 and 1985 could be correlated with improvements in particulate and sulphur dioxide levels over the same period.
Monteiro and Benicio	1987	São Paulo, Brazil	1,016 children surveyed. 29 percent had current respiratory disorder. No difference between socioeconomic groups in relation to overall prevalence of ARI.
Morbidity group: through skin and mucous membranes			
Ganapati	1983	Bombay, India	Leprosy in squatter settlements was 22/1,000 compared to 6.9/1,000 for city as a whole.
Kleevens	1966	Singapore	Hookworm: prevalence was 2 percent for squatters; 1 percent for apartment dwellers.
Pierce et al	1962	Guatemala (general)	Hookworm: prevalence of hookworm in poor urban areas was 4 percent and zero in wealthy urban areas.
Yan et al	1978	Malaysia (general)	Hookworm: prevalence of hookworm in poor urban areas was 5 percent and zero in wealthy urban areas.
Morbidity group: arthropod-borne			
Zicker	1988	Goiania, Brazil	Relative risk of Chagas' disease for patients claiming social security was 2.8 for socioeconomic class II and 2.2 for socioeconomic class III in comparison to class 1 claimants for invalidity benefits. Cases with Chagas were more involved in heavy labour.
Zicker et al	1990	Goiania, Brazil	Prevalence of *Trypanosoma cruzi* infection in active anual workers of 12.6 percent. Compared to a national survey which found a mean of 7.5 percent in rural areas. In those with the infection, 44 percent showed ECG abnormalities, whereas those workers without *Trypanosoma cruzi* showed ECG abnormality prevalence of 15.1 percent.
Morbidity group: through gastro-intestinal tract			
Benicio et al	1987	São Paulo, Brazil	Diarrhea in lowest socioeconomic stratum was 13.1 episodes (/100 children months), compared with 9.6 episodes in next stratum and 3.6 episodes in upper stratum.

Table 2–2. (continued)

Author(s)	Year	Location	Findings/Comments
Coll et al	1989	Dakar, Senegal	Of 139 cases of cholera 41 percent were unemployed; 18 percent were in irregular employment. The majority of cases originated from houses containing over 30 residents. Only 18 percent of cases' houses had running water and 36 percent had sanitation facilities.
Elsdon-Dew	1953	Durban, South Africa	Compared slum Cato Manor with muncipal housing scheme. Prevalences of *Ascaris* 50 percent and 20 percent respectively.
Kakande	1971	Kampala, Uganda	Compared slums and housing estate. Out of *Ascaris*, *Trichuris* and hookworm only the latter was significantly higher in slums.
Killewo et al	1990	Dar es Salaam, Tanzania	Prevalence of hookworm in a poor urban district was associated with low socioeconomic status, but prevalence of *Ascaris* was not.
Kleevens	1966	Singapore	*Ascaris*: prevalence was 63 percent among squatters; 9 percent for apartment dwellers.
Kloos et al	1987	Addis Ababa, Ethiopia	Morbidity survey (four week recall) in low and high socioeconomic kebele, 20 percent in poor kebele reported diarrhea and other abdominal conditions, 11 percent in other kebele.
Kouray and Vasquez	1979	Panama City, Panama	Of 1,819 infants with diarrheal diseases, 46 percent came from slums, 23 percent from shanties, and none from better housing.
McCullough	1972	Mwanza, Tanzania	Investigating the role of socio-economic status on *Ascaris* infection . Th e author studied 6,000 residents in 3 urban sectors and 1 rural sector in Mwanza. *Ascaris* was more prevalent in the 3 urban sectors. Higher socioeconomic status did not confer reduced infection in any area.
Pierce et al	1962	Guatemala (general)	Prevalence of *Trichuris* in poor urban children was 9 percent and 4 percent among more wealthy urban children.
Soh et al	1973	Seoul, South Korea	High intensity infection of *Ascaris* occurred in poorer parts of Seoul and parts of Seoul using vault latrines than in wealthier areas with sewerage.
Ulfah et al	1981	Yogyakarta, Indonesia	A lameness survey of 16,159 families in rural and urban areas found polio lameness rate of 9/10,000 children. In preschool children this rate was 22/10,000. Authors observe that urban areas are not better.

2.8 Studies on intra-urban differentials in diseases transmitted by airborne infections are rare. Monteiro and Bencio (1987) found no difference in acute respiratory infection (ARI) between socioeconomic groups of São Paulo. ARI is an under-researched urban health problem in developing countries, and there is a need for more studies to assess intra-urban differentials in ARI. The difficulty of diagnosis and measurement of ARI is a major constraint to the development of such research. Appropriate methods for measuring ARI incidence at the community level are only gradually emerging.

2.9 Studies on intra-urban differentials in leprosy and hookworm are available; but, interestingly, there are few such studies on skin diseases such as scabies, trachoma, or conjunctivitis.

Similarly in the arthropod-borne diseases, there are few studies that indicate differentials in urban malaria or dengue.

2.10 In terms of psychosocial diseases and trauma there is a growing literature on differentials in mental health within cities. Iyun (1989) and Mari's (1987) studies indicate a higher prevalence of mental illness in low income, physically deteriorated areas.

2.11 Nutritional status receives substantial attention in urban health research, perhaps because there are now clear guidelines on how to measure it. A number of studies provide a clear picture of intra-urban differentials in nutritional status, with poorer groups being at a distinct disadvantage in nutritional terms.

Causes of Death in Urban Areas

2.12 The many different ways of classifying cause of death led to problems when comparing results of different studies or health information systems. However, the studies summarized in Table 2–3 present a general picture of urban populations suffering the "worst of both worlds." They experience the problems of underdeveloped populations (deaths from infectious diseases and a predominance of postnatal deaths over neonatal deaths) and the problems of industrialized populations (deaths from neoplasms, heart disease and accidents). Again, Brazil provides the best data due to the more complete registration of deaths. Below, more light is shed upon the relative importance of different causes of death when studies of particular vulnerable groups are considered.

Mortality Among Urban Vulnerable Groups

2.13 Table 2–4 reviews studies that examine mortality among vulnerable groups in urban areas. In this case the vulnerable groups are classified as children, women, and the elderly. Infants and children up to five years old living in slums, squatter settlements, or shantytowns die from the same infectious diseases as their rural counterparts—measles, diarrhea, malaria, and acute respiratory infections (ARI). Many of these diseases are associated with environmental problems, but this link is not explicitly addressed in the studies. There is a shortage of data on children between the ages of 5 and 19. The PAHO (1988) study of state capitals in Brazil indicated that motor accidents were the leading cause of death for 5–14 year olds, while homicide was the leading cause of death for 15–19 year olds. It appears that once the poor urban child is old enough to leave the home environment independently, he or she becomes exposed to death associated with the modernizing or industrializing of the city. These deaths are not so closely linked to environmental problems. More research is needed into the causes of death of 5–19 year olds, particularly in urban Asia and Africa.

2.14 The gender differentials in infant mortality, summarized in Table 2–4 under "women" as the vulnerable group, are most likely to be associated with differential care rather than differential exposure to the environment. The elderly is another vulnerable group that is inadequately researched and is only gradually receiving attention in health and development literature. In slum communities the elderly are often found in households with the lowest income and expenditure (Sarveswara Rao and Sarma 1989).

Table 2–3. Summary of Literature on Causes of Death in Urban Areas of Developing Countries

Author(s)	Year	Location	Findings/Comments
Adedoyin and Watts	1989	Ilorin, Nigeria	Found most common single cause of death for children born in a five year study period in indigenous area of Ilorin was measles, followed by diarrhea, malaria and anemia. Infant mortality rate was 130/1,000 live births.
Greenberg et al	1989	Kinshasa, Zaire	38 percent of children admitted to hospital in Kinshasa had malaria. Case fatality was 21 percent. Over 80 percent of child malaria fatalities were under 5 years old.
Guimaraes and Fischmann	1985	Porto Alegre, Brazil	Predominance of postnatal over neonatal mortality in the shanty towns and vice versa in the nonshanty towns. 65 percent of deaths in nonshanty town infants caused by problems of gestation, delivery or the puerperium and only 25 percent by pneumonia, influenza, infectious intestinal diseases or septicaemia. In contrast 51 percent of shanty town deaths due to these latter causes. Mortality from these causes was also higher.
PAHO	1988	Belo Horizonte, Brazil	Using the NCHS classification the ten leading causes of death were: diseases of the heart 19 percent; malignant neoplasms 12.5 percent, cerebrovascular disease 10.7 percent, perinatal conditions 9.2 percent, accidents 6.5 percent; pneumonia and influenza 4.5 percent; coronary obstructive pulmonary disease and allied conditions 3.1 percent; diabetes mellitus 2.6 percent; chronic liver disease and cirrhosis 2.5 percent. Motor vehicle accidents constituted 20 percent of all deaths in the 5-14 year age group; for 15-19 year olds homicides were the leading cause of death (12.4 percent) of total — followed by malignant neoplasms. At ages over 50, chronic degenerative diseases constituted 60 percent of total deaths in the age group.
Phillips	1989	Hong Kong	In 1948 pneumonia, tuberculosis and enteritis caused 23 percent, 15 percent, and 13 percent of deaths respectively. In 1985 neoplasms, heart disease and cerebrovascular disease account for about 58 percent of all deaths. Infectious and parasitic diseases had fallen to 3 percent of total deaths. The authors point to the influence of population aging as a factor in increased chronic disease.
Rummel	1987	São Paulo, Brazil	Mortality rates for traffic accidents and homicides were highest for the unemployed and lowest for professionals.
Victora et al	1988a	Porto Alegre, Pelotas, Brazil	Infants weighing less than 2,500 g at birth were, respectively, 2.2, 3.3 and 12.8 times more likely to die due to diarrhea, respiratory infections and other infectious diseases respectively than those weighing more than 3,500 g. Compared to infants weighing more than 3,500 g, infants weighing 2,000-2,499 g were twice as likely to die and those 1,500-2,000 g were nine times as likely to die.
World Bank	1984	São Paulo, Brazil	Infectious diseases accounted for a third of all infant deaths in periphery (poorer). Neonatal deaths predominated over late infant deaths in more affluent areas; the reverse was true for the periphery. While cardiovascular deaths were the leading cause of death in all sub-areas, they made up 20 percent deaths in core areas and 10 percent in periphery.
World Bank	1988	Bolivia (general)	The two single main causes of death in urban Altiplano Bolivia for children under five years were diarrheal and parasitic disease (58 percent) and acute respiratory disease (6 percent).

Table 2–3. (continued)

Author(s)	Year	Location	Findings/Comments
World Bank	1990	China (general)	Rural areas are more affected by hypertension related disease, liver cancers (linked to *hepatitis B* infection), suicides and injuries. Urban areas are more affected by chronic diseases related to smoking and diet including stroke and coronary heart disease (particularly urban males).

Morbidity Among Urban Vulnerable Groups

2.15 Table 2–5 summarizes studies which measure morbidity of particular groups in the urban environment. Most of this literature selects children as the study group. A large number of studies find high prevalence of diarrhea and helminth infection in slum or squatter children. Many of these studies also measure nutritional status and find high rates of malnutrition (from 34 percent to 77 percent). Within this category of studies there is a particularly wide range of countries represented. Out of the twenty two studies only two (Pandey et al 1987, de Romana et al 1989) examine childhood respiratory infections. This is another indication of the need for further research on this health problem.

2.16 The other two vulnerable groups covered in Table 2–5 are women and workers in particular occupations. Occupational health is a specialized field, and a comprehensive literature search in the field was not conducted for this report. A search of this specialized literature may be worthwhile.

2.17 The studies reviewed in this section tend to establish the link between urban poverty and ill health in a descriptive way but fail to identify the important intermediate variables. In the next section, studies that address urban environmental factors as intermediate variables are reviewed. It is only by examining this next set of studies that the question of the relative impact of environmental problems in urban areas of developing countries can be addressed.

Table 2–4. Summary of Literature on Mortality Among Vulnerable Groups in Urban Areas of Developing Countries

Author(s)	Year	Location	Group	Findings/Comments
Vulnerable group: children				
Adedoyin and Watts	1989	Ilorin, Nigeria	Children under five years.	IMR = 130/1,000 live births. under five years Most common cause of death was measles, followed by diarrhea, malaria, anaemia.
Bisharat and Zagha	1986	Amman, Jordan	Slum children	Infant mortality in squatter areas fell from 68/1,000 to 55/1,000 from 1980-1985. Sex differentials in survival were marked: female deaths were 62/1,000 male deaths were 40/1,000.
PAHO	1988	State capitals, Brazil	5-14 year olds	Mortality in 5-14 year olds constituted 3.2 percent of total mortality. Leading cause of death is motor vehicle accidents (20 percent of deaths).
			15-19 year olds	Leading cause of death for 15-19 year olds is homicide (12.4 percent of the total) followed by malignant neoplasms.
PAHO	1988	State capitals, Brazil	Children less than 1 year	Examining the five leading causes of death in infants in state capitals, Brazil: conditions originating in the perinatal period cause 37 percent of infant mortality; acute respiratory infections 14.6 percent; intestinal infectious diseases 14.5 percent nutritional deficiencies 6.9 percent and congenital abnormalities 6.2 percent.
Singhal et al	1986	Gorakhpur, India	Infant squatters	IMR = 99/1,000.
Victora et al	1988a	Porto Alegre and Pelotas, Brazil	Perinatal	Compared with infants weighing 2,500 g or more at birth, low birthweight infants were 2.0 times more likely to die of diarrhea 1.9 times more likely to die of respiratory infections, and 5 times more likely to die of other infections. Overall low birthweight was found to be associated with an increased risk of death due to infectious diseases.
World Bank	1988	Bolivia (general)	Children under 5 years	In Altiplano urban Bolivia diarrheal and parasitic disease accounted for 58 percent of deaths in children under five years and acute respiratory disease 6 percent.
Vulnerable group: women				
Anson	1988	Israel (general)	Women	From urban Israeli population data of 1983, Anson found that although female mortality in urban areas is higher at low standards of living, when living conditions improve female mortality declines are faster and more pronounced.
Bisharat and Zagha	1986	Amman, Jordan	Female children in slums	Using the child mortality index, deaths per thousand in children under five were: males 46/1,000 and females 77.5/1,000 live births.

Table 2–4. (continued)

Author(s)	Year	Location	Group	Findings/Comments
Clemens	1988	Dhaka, Bangladesh	Female children in slums	Analyzed 38 children from mid to low income areas who had died under 6 years old and 228 controls. Found that low levels of family wealth and dependence on daily wages was a predictor of mortality in boys. Female deaths were independent of socioeconomic status. The authors conclude that differential care of infants may be a factor in gender difference in mortality.
Vulnerable group: elderly				
World Bank	1989	São Paulo, Brazil	Elderly	A review of death records for 1 August, 1973, when acute sulphur dioxide levels were recorded, showed deaths among elderly were 50 percent higher than normal.
World Bank	1989	São Paulo, Brazil	Elderly	Prevalence of chronic disease, and particularly multiple chronic diseases, was substantially higher in poor and middle-class elderly than in rich. Prevalence of mental illness was also much higher among poor elderly and individuals living in poor neighborhoods.

Table 2–5. Summary of Literature on Morbidity Among Vulnerable Groups in Urban Areas of Developing Countries

Author(s)	Year	Location	Group	Findings/comments
Vulnerable group: children				
Auer	1989	Manila, Philippines	Smokey Mountain scavenger children	Helminths and nutrition: survey of 238 slum children 8 months –15 years. Prevalence of 92 percent *Trichuris*, 80 percent *Ascaris*, 10 percent hookworm. Eighty-four percent had at least 2 species of parasites. Thirty-two percent *E. Coli*, 21 percent *E. histolytica*, 20 percent *Giardia*. Height for age of 77 percent of children aged 8 months–11 years was more than 2 standard deviations below the median of reference (NCHS).
Bhatnagar and Dosaij	1986	Delhi, India	Slum children	Diarrhea: incidence of diarrhea averaged 8 episodes per child per year. Highest incidence (12) was in slum with poorest sanitary conditions.
Bundy et al	1988	Kuala Lumpur, Malaysia	Slum children	Helminths: survey of 1,574 slum children, prevalence of 63 percent *Trichuris*, 50 percent *Ascaris*, 5 percent hookworm.
Burton	1976	Lima, Peru	Squatter children	Nutrition: 34 percent of children were malnourished (Gomez I, II, III), 56 percent had at least one type of intestinal parasite.
Chac-Tai	1989	Macao City, Macao	School children	Helminths: 1,309 school children. Prevalence of *Ascaris* 13 percent, *Trichuris* 11 percent. Piped water and piped sewage, cement roads were available. Association of infection was found with Chinese vegetables (night soil was used as fertilizer) and transmission via immigrants.
Deborah et al	1986	Ludhiana, India	Slum children	In the division of Ludhiana least well served by water and sanitation facilities, 55 percent of children aged 6–42 months were malnourished; 34 percent of these were severely malnourished. Proportionately, females were more malnourished. Female children of rural migrants were more severely malnourished than other children measured. Fifty-five percent of malnourished children had history of recent diarrheal disease.
Fashuyi	1988	Lagos, Nigeria	School children	Helminths: 94.7 percent of pupils at school in an urban slum in Iwaya, Lagos, were infected with helminth ova compared to 51.8 percent of school children in a rural area. Worm infection rates and load were heavier in Iwaya children.
Forrester et al	1988	Coatzacoalcos, Mexico	Shanty town	Helminths: 2,098 individuals (90 percent response for 428 households). High incidence of *Ascaris* and *Trichuris*. Heavily infected individuals were grouped in households.
Giugliani et al	1987	Porto Alegre, Brazil	Children over 1 year	Nutrition: case control study of malnourished and normal children in a squatter settlement. Found social determinants were stronger antecedents of malnutrition than the biological

Table 2–5. (continued)

Author(s)	Year	Location	Group	Findings/comments
				determinants. History of diarrhea and respiratory infection were also important antecedents of malnutrition.
Greenberg et al	1989	Kinshasa, Zaire	Children	Malaria: 38 percent of child hospital admissions were malaria cases. There was a 21 percent case fatality rate. Over 70 percent of child malaria cases were children less than five years old. Over 80 percent of those who died were also less than five years. Increase in malaria admissions is related to the emergence of chloroquine resistant malaria in Kinshasa.
Grinstein et al	1989	Buenos Aires, Argentina	Slum children less than	Diarrhea: diarrhea was twice as common in children aged less than two 2 years, as in other age groups. *Rotavirus* was identified in 5.5 percent of cases.
Hettiarachi et al	1989	Galle, Sri Lanka	Slum children less than 14 years.	Helminths: prevalence of intestinal parasites was 95 percent *Trichuris* (95 percent); *Ascaris* (69 percent); *Necator* (17 percent).
Meeham	1990	Shanghai, China	Slum infants	Breast-feeding: exclusive breast feeding of infants by urban mothers for at least 4 months had declined from 59 percent in 1950; to 35 percent in 1974 and 12 percent in 1984. The author notes the importance of breast-feeding in protecting health of infants.
Osinusi and Oyejide	1989	Ibadan, Nigeria	Slum children 0-5 years	Morbidity: the most common illness symptoms in children were nasal discharge (30 incidences per 100 child days), coughs (12) and fever (10). There was a higher incidence of fever, skin rash and diarrhea in the dry season. The authors suggest shortage of water as a factor. The highest incidence of diarrhea occurred in children aged 7-12 months and the highest skin rash incidence in children aged 37-60 months.
Pandey et al	1987	Nepal (general)	Children less than 2 years	Found a direct relation between reported hours per day near the stove by infants under 2 years and episodes of life-threatening acute respiratory infection.
Prabhakar Rao et al	1988	Pondicherry, India	Slum children 0-10 years	Nutrition: in a slum in Pondicherry children showed malnutrition levels of 39 percent (Grade I), 38 percent (Grade II), and 15 percent (Grade III). 67 percent of children had single or multiple parasites. 76 percent of children had coughs and 53 percent fever.
de Romana et al	1989	Lima, Peru	Slum children (newborn)	Respiratory infection: in Huascar, a peri-urban slum, there was 28 percent prevalence of upper respiratory tract infection and 15.5 percent prevalence of diarrhea. Rates of stunting and wasting in children increased progressively during the first year of life, despite average birthweight.
Reichenheim and Ebrahim	1986	Fortaleza, Brazil	Slum children	Nutrition: In 4 squatter areas in Fortaleza, 50 percent of families had per capita income of less than a third of minimum wages. Low intake of nutrients was due to missed meals, small meal volumes and low nutrient density in meals. Over 50 percent

Table 2–5. (continued)

Author(s)	Year	Location	Group	Findings/comments
				of children were consuming only 5 food types, although 26 were available in the same price range. The authors conclude that "choice" of foods could be improved even in poor urban families.
Reichenheim and Harpham	1989	Rio de Janeiro, Brazil	Children under 5	Accidents: in a survey of a slum found the age of the child was the most important determinant of accidents. Peaks in accidents were in the second or fifth year of life. Other associated factors were having a mother living with a partner, having a mother under stress or depressed, and being separated from one's mother for at least half the week because of the mother's need to work.
Sabir	1984	Lahore, Pakistan	Slum children	Nutrition: 73 percent of children were malnourished (Gomez) and 61 percent were stunted (Waterlow).
Stanton et al	1987	Dhaka, Bangladesh	Squatter children	Seventy-seven percent of children had scabies in a one-year study period. Sixteen percent infested for more than 6 months.
Stanton et al	1989	Dhaka, Bangladesh	Squatter children less than 6 years	In a study of 343 children in 51 slums, stool samples of children with and without diarrhea were taken. 51 percent of routine stools and 42 percent of diarrheal stools had parasites. *Ascaris* and *Trichuris* accounted for 80 percent of parasites in both stools. The authors note that parasite infections in urban Bangladesh are high and not necessarily diarrhea-related. Pathogens found by this study were not similar to rural infections found in Bangladesh.
Vulnerable group: women				
Bisharat and Zagha	1986	Amman, Jordan	Female children in slums	Nutrition: in 1981, 28 percent of 3 year old male children were below 90 percent of their reference weight for age, but 46 percent of females were below 90 percent of normal weight for their age.
Gao et al	1987	Shanghai, China	Women	Indoor pollution: prolonged exposure to oil volatiles from cooking at high temperature may be related to increased risk of lung cancer. Risks rose with frequency of cooking, with reported smokiness of the house and with reported eye irritation during cooking. Risks were highest with exposure to rapeseed oil fumes.
Giugliani et al	1987	Porto Alegre, Brazil	Mothers, slum dwellers	Forty-five percent of mothers in a squatter settlement are smokers. Fifty-eight percent suffered from medical problems such as anemia, hypertension, urinary infection, and sexually transmitted disease. One third of squatter settlement families describe alcoholism as a serious problem.
Sathyamala	1987	Bhopal, India	Women	Gynecological disease: following gas exposure, women had leucorrhoea (94 percent); pelvic inflammatory diseases (79 percent) and excessive bleeding (46 percent).

Table 2–5. (continued)

Author(s)	Year	Location	Group	Findings/comments
Sierra et al	1989	Costa Rica	Women	Cancer of the colon and breast is twice as common among urban women as among rural women in Costa Rica.
Tidke et al	1986	Bombay, India	Paralyzed children less than six years old.	Polio: A community lameness survey of slums. In 1986, male:female impairment ratio was 1.5:1. Authors observe this could be due to higher case fatality in females.
World Bank	1989	Cubatao, Brazil	Pregnant women	Proximity to petrochemical plants is correlated with spontaneous abortions.
Vulnerable group: workers				
Zhao-Yi Xu et al	1989	Shenyang, China	Manual workers	Study found a threefold increase in lung cancer risk among men working in the nonferrous smelting industry where there is heavy exposure to inorganic arsenic.
Zicker et al	1990	Goiania, Brazil	Active manual workers	Found seroprevalence of *Trypanosoma cruzi* infections of 12.6 percent of manual workers screened. Of these infected cases, 44.4 percent showed ECG abnormalities compared to 15.1 percent ECG abnormality prevalence in workers without infection.
Zicker	1988	Goiania, Brazil	Workers	Found Chagas' disease was the cause of 4.2 percent of all sickness benefits and 9.1 percent of invalidity claims. Rate of 4,212 potential future productive years of life lost per 10, 000 workers per year. Cases of Chagas's were younger, involved in "heavy" activities, and were more recent migrants to the city than the control group.

III. A REVIEW OF LITERATURE THAT CAUSALLY LINKS URBAN ENVIRONMENTAL CONDITIONS TO HEALTH IN DEVELOPING COUNTRIES

3.1 Studies that attempt to establish the causal links between urban health and the urban environment are fewer in number than the descriptive analyses reviewed in section II. One reason for this is the complexity of the acknowledged synergism of physical, social, economic, political and cultural elements in the urban ecosystem (WHO 1990). This section reviews studies that have established associations between disease and mortality with particular urban environmental factors.

Studies That Attempt to Causally Relate Urban Environmental Conditions and Mortality

3.2 Table 3–1 shows some recent studies on urban mortality that have attempted to establish a hierarchy of interacting causal variables. The analysis of the route from environment to health consequences is arguably more difficult in urban than rural areas, and studies attempting to trace the cause of a particular mortality or morbidity pattern often discover contradictory (and sometimes counterintuitive) messages emerging from the data (for example M'Gonigle 1933). The studies should be interpreted with caution: in some, associations of environment and mortality are derived from demographic data (Anson 1988), while others focus on a particular age or socioeconomic group.

3.3 The relationship between infant and child mortality with the quality of and access to water has been explored in a number of studies. The studies of Pickering 1985; Monteiro and Benicio 1987; and Merrick 1983, undertaken in the Gambia and Brazil, each linked water access and quality to infant mortality. Interestingly, household access to an "individual" water supply emerged as an important feature within the water variable. However, studies present varying conclusions as to which of a number of variables are of importance. Victora et al 1988b, conducted a particularly rigorous study of infant mortality in Pelotas and Porto Alegre, Brazil. They found that infants from households using public standpipes or wells were 4.8 times more likely to die of diarrhea than those from households with in-house piped water. Merrick, while observing that infant mortality declined by 20 percent with the advent of increased access to water in Brazil, noted that maternal education accounted for 34 percent of mortality decline. Tekce and Shorter in Amman note the mutual interaction of several factors.

3.4 The existence now of studies focusing on infant mortality—particularly that of the urban poor who are still afflicted by acute, preventable mortality—is encouraging. However, the number of studies cited here linking water supply and infant mortality do not necessarily indicate that mortality in urban areas of developing countries is dominated by deaths of infants or from water-related disease. Deaths from diarrheal and water-related diseases may form the predominant mortality burden for some infants in some areas, but for other groups a different pattern may prevail. For example, again in Porto Alegre, Brazil, Guimaraes and Fischmann note that in shantytowns 51 percent of infant deaths are due to infectious intestinal diseases, pneumonia, influenza or septicemia. But in nonshanty areas these account for only 25 percent of mortality, with 65 percent of deaths caused by problems of gestation, delivery, or the puerperium. PAHO, in examin-

Table 3–1. Summary of Studies That Causally Relate Urban Environmental Conditions and Mortality

Author(s)	Year	Location	Findings/comments
Anson	1988	Israel	In 72 Israeli towns the author found that living arrangements (overcrowding), which might be expected to affect mortality directly, were the poorest predictor of relative mortality levels. The best indicators of mortality were car ownership; household income (employment) and education. The author points out the importance of public housing, rent subsidy and low mortgages as important factors in decreasing the risks of mortality related to housing.
Mantorska	1989	Poland (general)	Life expectancy in agricultural areas is 69 years. Where urbanization rate is over 95 percent and density of population is high life expectancy of new born males is 65 years.
Merrick	1983	Brazil	Increased access to piped water accounted for about 20 percent of observed decline in infant deaths. However, increased maternal education accounted for 34 percent of mortality decline—more than any other factor.
M'Gonigle	1933	Stockton-on-Tees, United Kingdom	Mortality rates in city, in an original slum population and in slum families moved to better accomodation were measured between 1923-1927 and 1928-1932. Crude mortality remained static in the city, declined by 10 percent in the original slum, and increased by 30 percent in the new housing area; linked with declining nutritional intake.
Monteiro and Benicio	1989	São Paulo, Brazil	Reduction in infant mortality between 1973 and 1986 linked with improved water supply and sanitation.
Pickering	1985	Bakau, Gambia	Retrospective study of child mortality under 3 years. Found risk of death in households using public taps twice as high as for those with yard connection.
Tehce and Shorter	1984	Amman, Jordan	Squatter settlements. Determinants of infant mortality (in order) were: mother's education, housing quality, head's occupation and household income. Housing quality was major determinant of personal hygiene.
Timaeus and Hill	1985	Adana, Turkey	In a survey of 745 households, child and infant mortality was strongly associated with overall dwelling quality (as measured by building material) and sanitation facilities (as measured by presence of inside toilet); source of drinking water was an important independent variable.
Victora et al	1988b	Pelotas, Porto Alegre, Brazil	Infants in houses sharing a tap with neighbors are more likely to die of diarrhea (even after adjusting for confounding factors) than those from houses with in-house piped water. Infants from houses using public standpipe or well are 4.8 times more likely to die of diarrhea than those from houses with in-house piped water (result significant at 1 percent level).

ing the causes of death in infants in state capitals of Brazil, found that conditions originating in the perinatal period comprised 37 percent of infant mortality, followed by ARI with 14.6 percent of deaths.

3.5 The literature seems to be biased toward the tangible links of poor **physical** environment (of which dwelling and water quality are indicators) and mortality, rather than toward analysis of the more complex socioeconomic and psychosocial variables influencing urban mortality. Table 3–1 also shows the demographic bias of the studies represented: infant mortality is examined more often in urban developing country studies than adolescent or adult mortality patterns. Nonetheless, studies of cause of death in urban areas in the developing world point to the increasing mortality burden of chronic disease and psychosocial problems: PAHO in Brazil identified ten leading causes of death in Belo Horizonte, Brazil: diseases of the heart, malignant neoplasms, and cerebrovascular diseases comprised 42.4 percent of mortality. For some age groups the psychosocial risks of the environment seem particularly severe: for 15–19 year olds in Belo Horizonte, the major cause of death is homicide, followed by malignant neoplasms.

3.6 Descriptive studies of general adult mortality do exist (internal World Bank Report 1990), and data can be disaggregated for urban areas (see Tables 2–1 and 2–3); but there are few studies that have attempted (or managed) to identify causal mechanisms influencing adult health in the urban environment. Those that do tend to originate from developed countries—for example the *Black Report* and the *Health Divide*, which examine the socioeconomic antecedents of mortality in the UK (Townsend et al 1988), and most produce results specific to a certain urban locale (Anson 1988).

3.7 Reviewing the literature shows that when links of urbanization, and adult health are established, the association of a complex of psychosocial variables and adult mortality is largely idiosyncratic to that city and that people at that time. Thus, while one might intuitively assume that mortality from increasing stress-related conditions such as hypertension are a peculiarly urban problem in general terms, in some countries another pattern may emerge. For example, in China, data indicate that rural mortality is more affected than urban by hypertension related disease, as well as suicides and injuries. Given the increasing mortality burden from chronic diseases in cities of the developing world, more data on psychosocial antecedents of disease and mortality are needed urgently. The next section reviews literature attempting to relate causally the urban environment with morbidity patterns in the developing world.

Studies That Attempt to Causally Relate Urban Environmental Conditions and Morbidity

3.8 Table 3–2 reviews the literature that has attempted to establish causal links between urban environment and ill health. The studies analyzing morbidity are much more numerous than those tackling mortality, but even so they do not show a comprehensive or uniform pattern of linkages between urban environment and health. Again the study of infant morbidity and its relation to water accessibility, quality, and sanitation shows some of the strongest associations of environmental variables and disease outcomes. Koopman et al., Fashuyi, Kan et al, and Mackie et al, each establish the association of parasite burdens in children with poor sanitary environments. Such studies seem to imply an apparently simple relationship between improved hygiene and environ-

Table 3–2. Summary of Studies Which Attempt to Causally Relate Urban Environmental Conditions and Morbidity

Author(s)	Year	Location	Findings/comments
Azurin and Alvero	1974	Bacolod City, Philippines	5 year study in 4 communities showed that the provision of human waste disposal facilities reduced cholera by 68 percent while provision of safe water decreased it by 73 percent. If toilet and water, reduction was 76.
Bapat and Crook	1984	Poona, India	In a survey of 605 households, authors found a negative correlation of morbidity and per capita provision of latrines of 43.1 percent (for children 0–5 years) and 32.7 percent (for total population). Dampness of huts was also significant: 75 percent of all sick and 80 percent of those ill with respiratory problems were living in damp conditions.
Black et al	1989	Huascar, Peru	Newborns in a peri-urban slum had nearly 10 episodes of diarrhea each in the first year of life. Transmission was related to animal feces, contaminated food and water, and by direct person to person contact. The contamination of weaning foods through inadequate preparation or cleaning of utensils was implicated.
Burchell	1981	United Kingdom (general)	1976 general household survey was examined to identify factors influencing long-standing illness in adults. Age and sex were most important. Controlling for these rates rose with falling socioeconomic status. Other factors were overcrowding; smoking; education; and marital status.
Burr et al	1981	South Wales (general)	Indoor air pollution from open coal fires and damp housing conditions were associated with increased respiratory disease symptoms.
Chac-Tai	1989	Macao city, Macao	Prevalence of 13 percent *Ascaris* infection in 1,309 school children was found to be associated with Chinese vegetable (night soil was used as fertilizer) and transmission via immigrants.
Crean et al	1987	Bombay, India	Dharavi slum. Socioeconomic status as measured by house conditions and possessions, and length of residence, was significantly associated with nutritional status. Maternal education was not.
Fashuyi	1988	Lagos, Nigeria	Of school children in an urban slum 94.7 percent were infected with helminth ova compared to infection prevalence of 51.8 percent in pupils of a rural school. The author concludes that the differences found were due to population concentration in the slum, low level of hygiene, poor drainage, and absence of facilities.
Feachem et al	1983	Gaborone, Botswana; Ndola, Zambia; Kumasi, Ghana	Mixed findings on parasite levels suggest that provision of superior water and sanitation to small cluster of houses may not protect families if overall level of fecal contamination of environment is high. Sample sizes and response rates low.
Gazin	1989	Bobo Dioulasso, Burkina Faso	Malnutrition: a study of 1,351 infants 9–23 months in rural areas and urban Bobo-Dioulasso. No difference was found in levels of malnutrition in rural and urban areas. In 2–4 year olds in Bobo, severe malnutrition was significantly associated with living in peripheral spontaneous settlements and in old quarters in the center of town (9 percent and 4 percent respectively). Higher levels of

Table 3–2. (continued)

Author(s)	Year	Location	Findings/comments
Gazin			malnutrition were found in the dry season for urban children, when urban basic foodstuffs were most costly; and for rural children in the wet, harvest season.
Georges-Courbot et al	1990	Bangui, Central African Republic	Cohort of children followed from birth to age 2. Monitoring of *Campylobacter* infections found that these were statistically associated with live poultry and lack of piped water in houses.
Guerrant et al	1983	Pacatuba, Brazil	Diarrhea: rates at all ages in 297 study particpants were significantly higher in poor urban and poor rural areas than the nonpoor central urban area. Diarrheal risks were 2.2 times higher for children in households without pit toilets (compared to those with pit toilets).
Hunt et al	1986	Edinburgh, U.K.	Respiratory/bronchial symptoms, headaches and diarrhea were more common among children living in damp housing. The effect of damp was independent of the effect of low income or smoking in the household.
Kan et al	1989	Malaysia	In a study of rural plantations and urban slums the (general)prevalence and intensity of *Ascaris* and *Trichuris* infection was higher among slum children. Hookworm infection was similar in both areas. The authors suggest an association of infection with poor sanitation and over crowding.
Kleevens	1966	Singapore	*Ascaris*, hookworm, and *Trichuris* prevalence rates were 9 ; 1 percent and 28 percent respectively for flat dwellers and 63 percent; 2 percent, and 58 percent among squatters.
Koopman et al	1981	Cali, Colombia	Diarrhea and vomiting were more common in school children attending schools with lower hygiene scores. Strongest associations for diarrhea were related to poorly maintained sanitation facilities.
Kouray and Vasquez	1979	Panama City, Panama	Enteropathogenic *E. coli, Shigella* and *Salmonella* were absent from children in the best housing. In other housing, 8 percent of children had one or more pathogens in their feces.
Lenz	1988	Jakarta, Indonesia	Measured prevalence of malaria and diarrhea. Risk factors were classified into 3 areas: socioeconomic, mobility and environmental. Only environmental variables associated with diarrhea and malaria. Of maximum significance were slum location, bathing place, electricity availability or not, drinking water source, and housing material.
Mackie et al	1956	North Carolina, United States of America	*E. histolytica:* prevalence rates were 6 percent for those with an inside flush toilet; 12 percent for those with a shared flush toilet and 58 percent for pit latrines. Infection was also associated with type of water supply and garbage disposal facilities.
Mason and Stephens	1981	Global	Review of linkages between housing and morbidity. Conclude clearest housing-health associations are with accidents, diarrhea and ARI.
Meslet	1989	Maradi, Niger	Nutrition: relating malnutrition levels in 523 0–5 year olds author found significant associations with; age of the mother— levels of malnutrition were

Table 3–2. (continued)

Author(s)	Year	Location	Findings/comments
Meslet			higher where mothers were less than 20 years or over 30 years; area of residence and access to washing facilities. Levels of malnutrition were 24 percent in the "new" zone (70 years old); 16 percent in old town; 13 percent in the commercial area and 5 percent in the planned extension zone (60 years old). Prevalence of malnutrition in families with individual washing facilities were 4 percent, with collective washing areas 6 percent, and 100 percent where no facilities were available.
M'Gonigle	1933	Stockton-on-Tees, United Kingdom	Nutrition: in a study of households moved from slums to improved housing found that modest increases in rent resulted in decreased household dietary intake.
Molbak et al	1989	Monrovia, Liberia	Food contamination: a study of food and water contamination in a rural village and urban slum found that most urban households stored food and 63 percent of stored food samples were heavily contaminated with bacteria. Rural households did not store food so often and only 39 percent of food samples were contaminated. Rural families did not store baby foods but 81 percent of baby foods in urban households were contaminated. At water source in the slum only 19 percent of samples were contaminated but 46 percent of stored water was contaminated. The authors conclude that environmental health problems in slums require attention to storage and hygiene, as well as provision of safe sources of food and water. Rural areas are affected less due to low storage levels.
Moore et al	1965	Urban areas, Costa Rica	Amoebiasis: prevalence was associated with one source of piped water.
Pereira and Andrade	1988	Rio de Janeiro, Brazil	104 rodents were captured in an urban slum area. Leptospirosis was identified in 23 percent of the animals. Human leptospiral infection is endemic in Rio and rodents are thought to be a major source of infection.
Pickering	1985	Bakau, The Gambia	Nutrition: in a study of 493 urban children a significant association was found between social factors related to improved living standards and heavier and taller children.
Reichenheim and Harpham	1989	Rio de Janeiro, Brazil	Accidents: in 599 children 0-5 years in an urban slum most reported accidents were falls (66 percent), cuts (17 percent), and burns (10 percent). Within a 15 day recall period, 4 percent had at least one type of accident requiring medical attention; 26 percent had an accident which was treated at home. In total, accidents accounted for 19 percent of all health problems. The authors conclude that quality of care in this environment is limited by socioeconomic conditions.
Richardson et al	1968	Rustenburg, South Africa	92 children. *Salmonella* (28percent) and *Shigella* still prevalent after provision of high quality water but no other sanitary improvements.
Rodrigues and Ferreira	1966	São Paulo, Brazil	Study of children with schistosomiasis in a working urban area of São Paulo found sites of transmission were two pits used as communal bathing pools.
Zhao-Yi Xu et al	1989	Shenyang, China	Lung cancer: after adjustment for smoking, the authors found significant increases in lung cancer associated with measures of exposure to air pollutants. Risks were twice as high among those who reported smoky outdoor environments and increased in proportion to years sleeping on beds heated by coal-burning stoves and to overall index of indoor air pollution.

studies seem to imply an apparently simple relationship between improved hygiene and environment and improved health. Other studies (for example, Richardson et al) point to a more complex synergism of environmental and social risk factors for disease. In some studies, socioeconomic status is an accurate proxy for the complex of variables acting upon urban health (Kouray and Vasquez, Pickering).

3.9 Also included in Table 3–2 is a study from Monrovia, Liberia, by Molbak et al. that concludes that water related environmental health problems in urban areas are linked to storage and hygiene factors as well as to "safe" water variables. In turn, Tekce and Shorter implicated housing quality as a predictor of improved personal hygiene.

3.10 Mason and Stephens in 1985 produced a table linking disease associations and housing factors. To the authors' knowledge, some of these associations have not been adequately demonstrated in the urban environment. Our final table, Table 3–3, summarizes some variables of the urban **physical** environment, diseases associated with them, and those studies reviewed that have demonstrated the linkages.

3.11 It is interesting that Mason and Stephens's global review of 1981 concluded that the clearest physical associations of housing and health were for accidents, diarrhea, and ARI. Studies represented here show a similar correlation: diverse data from UK (Burr et al 1981), India (Bapat and Crook 1984) and China (Zhao-Yi Xu et al 1989) all show strong associations of ARI and indoor air pollution. Links of diarrheal diseases and water variables are well represented. Reichenheim and Harpham report a series of accidents in children of a poor slum area in Rio de Janeiro, Brazil. Yet, caution is needed in the interpretation of the data reviewed: for example, Reichenheim and Harpham perceive that the health outcome (accidents) derives ultimately from a socioeconomic environment that limits quality of care. The hazardous physical environment becomes only an intermediate variable in this equation. Similarly, increased lung cancer in China is associated with air pollution, but only after controlling for the impact of smoking. Studies in Britain indicate that the antecedents of smoking can be associated with socioeconomic status (Townsend et al 1988).

3.12 Perhaps the most cautionary tale comes from the conclusions on relationships of health and urban environment in the classic "natural experiment" of M'Gonigle (1933) in Stockton-on-Tees. A project to improve the quality of life for slum dwellers in the United Kingdom was started in 1923. In a study of children of slum households moved to the new improved housing area, M'Gonigle and his colleagues found that infant mortality and nutritional status actually worsened in comparison to both the original slum area and to the city as a whole. The investigators found that physical surroundings of the slum dwellers had certainly improved in the new housing area, but the residents had severely skewed their household budgets away from food to afford the modest rent increases of the new houses. This, they concluded, had a severe impact on infant health. Follow-up studies of an environmental slum improvement project in Amman, Jordan, found a similar decline in nutritional status of infants over the project period (Bisharat and Zagha 1986). Such results imply that a great measure of caution is required in the interpretation of studies that seem to implicate particular physical variables in the urban environment. Housing and health links are intuitive and solutions seem almost graspable, but the complex relationship of household eco-

Table 3–3. Urban Environmental Features, Mortality, Disease Associations, and Urban Studies Attempting to Link Them

	Factor	Diseases/conditions	Studies attempting to show association
Shelter			
Temperature	Heat Cold	Lung cancers; ARI; burns	Bapat and Crook; Reichenheim and Harpham; Burr et al; Hunt et al; World Bank (Brazil).
Location	Pollution	Gynaecological; ARI; cancers	Fischer and Hofmeister;Sathyamala; World Bank (Brazil); Zhao-Yi Xu.
	Vector site	Malaria; dengue; rabies; hookworm; leptospirosis	Kleevens; Pereira and Andrade.
	Accidents Season	Burns; cuts; road accidents Skin diseases; fever; diarrhea	Osinusi; Reichenheim and Harpham; Rummel.
Spatial	Density between buildings	Psychosocial; communicable diseases; accidents	PAHO; Fashuyi; Burchell; Mason and Stephens.
	Density within buildings	Leprosy; TB; measles; psychosocial; cholera; ascaris; trichuris	Ganapati; Coll et al; Adedoyin and Watts; Kan et al; World Bank.
Structural	Flooring Walls Roofing Ventilation	Hookworm ARI Chagas ARI, headaches, cancers	Soh et al; Lenz; Bapat and Crook; Burr et al; Hunt et al; Pandey et al; Gao et al.
Water			
Quality/source		Typhoid; cholera; gastroenteric; hepatitis A; mortality; amoeba	Victora et al; Guerrant et al; Feachem et al; Monteiro and Benicio; Moore, de la Cruz and Vargas Medez; Richardson et al.
Quantity		Skin infections; trachoma; gastroenteric; schistosomiasis	Merrick; Osinusi; Victora et al; Georges-Courbot et al; Rodrigues and Ferreira; Osinusi and Oyeide.
Storage		Gastroenteric; filariasis; malaria; amoeba	Bhatnagar and Dosaij; Koopman; Lenz; Moore, de la Cruz and Vargas Medez; Fashuyi.
Disposal/sanitation		*Ascaris*; malaria; schistosomiasis; hookworm; cholera; shigellosis	Coll et al; Soh et al; Azurin and Aalvero; Fashuyi; Feachem et al; Bhatnagar and Dosaij.
Food			
Quantity	Overall Seasonal	Undernutrition; malnutrition	Bogin and Macvean; Datta Banik; Franklin et al; Mohan et al; Monteiro et al; Victora et al; Gazin.
Quality		Cancers	Jansen et al; World Bank (China); Sitthi-Amorn.

Table 3–3. (continued)

Factor	Diseases/conditions	Studies attempting to show association
Food		
	Malnutrition; alcoholism hypertension; coronary heart disease	Reichenheim and Ebrahim; Datta Banik.
Storage	*Salmonella*; *Giardia* *E. Coli*	Black et al; Molbak et al.
Disposal	*Trichuris*; *E. histolytica*	Mackie et al.

nomics and health must be included in any equation and, as Bisharat and M'Gonigle's studies indicate, this is often not done. To the authors' knowledge these are too few studies where the actual health implications of shifted household budgets have been fully explored in the urban environment. More data are needed on this area. The diversity of methodology and focus of the studies reviewed here indicates need for caution also, but as Table 2–8 shows, some light can be shed on the urban physical environment variables and their association to some morbidity states.

3.13 As noted earlier in this report, there are few analyses that have been consistently able to implicate specific environmental variables in the causation of chronic and psychosocial morbidity in urban areas of the developing world. Yet psychosocial and chronic diseases are becoming dominant causes of death in urban areas as diverse as Shenyang and Rio de Janeiro.

3.14 From the review of descriptive and analytic studies in urban areas of industrialized (European) and developing countries, it seems that the health impact of both chronic and acute morbidity (and consequent mortality) is upon the urban poor. Urban poverty is a complex proxy measure for a composite of deprivation extending from command over resources, education, social support, and self-esteem to housing quality and sanitation. But as a fundamental variable **poverty remains the significant predictor of urban morbidity and mortality**. The published data indicate that addressing the intermediate variables of the urban physical environment is a partial approach to improving urban quality of life. This review of literature on urban health in developing countries indicates the complexity required of analyses of the problems of urban health. It also points to the breadth of vision required of attempts to address these problems.

IV. CONCLUSIONS AND SUGGESTIONS FOR FURTHER STUDIES

Conclusions

4.1 Several conclusions emerge. First, there are relatively few good studies available on intra-urban differentials in morbidity and mortality. By contrast, specific studies of, for example, changes in a single variable such as water supply in rural areas are far more numerous. Second, the intra-urban mortality differentials are often great, especially but by no means only among children and infants. Third, the differences in disease and death among children are primarily due to the diseases of poverty and underdevelopment and are not unlike those of rural areas. Among adult males the mortality may be high but with an increased importance of trauma in various forms.

4.2 The correlation between poverty and a deficient home environment in cities is sufficiently close that separating them as causal factors in disease is difficult. In some chronic diseases, especially psychoses, the illness may lead to relocation to a poor area rather than the latter acting as cause.

4.3 As to how far epidemiological data combined with economic analysis can guide the development of priorities in infrastructure planning, we proceed with caution. Public health intervention, other than by specific vaccines and chemotherapy, is a relatively blunt and unsubtle instrument.

4.4 We suggest that most of the variation in infant mortality between areas within a city is due to the "infectious and parasitic" disease component with a smaller perinatal and obstetric component. The same may be true for the following four years of life (without the obstetric component.) In the following two decades of life, we suggest that mortality differentials may be due in men to communicable disease and violence and in women less from violence and more from obstetric causes. Specific occupational diseases may play a substantial role from fifteen years onward and communicable disease is likely to reappear as a major cause of intra-urban differentials in the elderly. These hypotheses are open to test: the main challenge is to collect better mortality data, especially the likely cause of death, from cities in developing countries. Occupational disease predictions would be improved by specific field studies, since occupational mortality is likely to be concealed among other routine diagnoses.

4.5 It is relatively easy to formulate hypotheses on the differential mortality of children within cities. The relations between scale and type of mortality in adults is less obvious and open to study; among the aged the relationship may revert toward the childhood pattern, although chronic diseases will loom much larger. Cumulative disability is also worthy of careful investigation. In the young, within any one city, the diarrheal disease rates (for morbidity or for mortality) are likely to vary more than the ARI rates, and, apart from the real practical difficulty of measuring both of them, might provide an indication of the likely benefits to be obtained from improving the water-sanitation system.

4.6 Within the home, certain improvements are more feasible and more likely to affect health than others. Where smoky indoor cooking fires are used, improvement in stove design would likely be cost-effective, as would improving the surface of house walls to reduce the occurrence of Chagas' disease. While hookworm may also be affected by house design, it will often be better dealt with by inducing the use of shoes.

4.7 The main causes of intra-urban mortality differentials among young children are communicable diseases. Attempts to control these may be by means of improving urban infrastructure or by specific medical methods: vaccines for viruses, vaccines or chemotherapy for bacterial diseases; chemotherapy for parasitic infections; and oral rehydration for the watery diarrheas. Can these be relied on to the exclusion of infrastructural improvements? This appears unlikely. It is difficult to provide excellent medical services for squatter populations. Moreover, the general level of preventable diarrheas may be so high and the limitations of oral rehydration such that to rely solely on medical interventions would achieve only limited success. Moreover, there are as yet no readily available and effective vaccines against dengue (and dengue hemorrhagic fever is a primary cause of pediatric mortality in Bangkok) or the rotaviruses, which cause much watery diarrhea.

4.8 Typically in cities, and especially the poorer parts of a city, the ratio of people to space is very high. Controlling the breeding of arthropod vectors of disease should be more practicable than in rural areas. However, the control of crowding is more difficult and immunization will tend to be the effective method to prevent those diseases spread by direct airborne transmission; among them, measles, whooping cough, and tuberculosis are particularly important. Nevertheless, we would deprecate any attempt to decide on social and planning improvements solely on health grounds, and while the diseases of crowding may require immunization strategies for control, overcrowding is a great evil on many grounds and requires substantial attention. In some regions, BCG vaccination appears to convey little protection against tuberculosis; we are still uncertain of the precise transmission route of leprosy; there is no satisfactory vaccine against type B meningococcal meningitis; and crowding is unlikely to reduce sexually transmitted diseases.

4.9 Simplistic views on any infrastructural improvement are likely to be mistaken. Few environmental improvements in cities are of the all-or-nothing type, so that investment choices are not simply between several possible interventions but between degrees of those interventions in various mixes. Also, environmental improvements tend to consist of rather large steps: from nothing to pit latrines to sewered pour-flush toilets to full sewerage rather than a continuous series of sanitation improvements. In some cases the step which brings most health gains has been identified; most would agree that the crucial step in water supply access improvements occurs when the tap is brought into the compound or household, for example. Where the main improvement is one of policing or enforcement, as with food hygiene in markets or occupational health, then a continuous sequence of small improvements is a better process once the initial legislation is in place.

Proposed Future Studies

4.10 What further research is needed, and what new insights can it hope to provide? There are some clear needs for further field research and also opportunities for additional analyses of existing data. There are also implications for the way in which routine statistical data are collected. While additional research on specific problems may produce definite solutions, we would caution against excessive expectations of detailed linkages of epidemiological and economic data. While great clarity can certainly be achieved, the many causes of most relevant diseases and the diverse benefits of environmental improvements mean that, while further research can clarify processes and understanding, epidemiology cannot rescue us from the difficulties of choosing between alternative improvements. It may narrow the range of options open to the rational planner but not remove the dilemma.

4.11 The single group that arouses most concern among those who look at developing country cities are the homeless. Knowledge about their numbers, health, and mortality is almost absent. We found a census of pavement-dwellers in Bombay, India, but it lacked age-structure and other relevant variables. For squatters and slum-dwellers census information on numbers is more widely available, but there is little on mortality and morbidity except data amalgamated with the rest of the urban population (and little enough of that with a population base). There is therefore an enormous need for both demographic and health information with a population base stratified by socioeconomic (or housing) category. Data similarly stratified on cause of death are also needed.

4.12 There are marked differences in the effort so far put into research on the topics considered in this paper. Water, sanitation, and diarrheal diseases have been extensively studied, and the addition of a study or two is unlikely to change our understanding markedly, although the bias of published work has been toward the rural scene. By contrast, domestic air pollution and acute respiratory infections have been much neglected, and there is ample scope for further understanding. General air pollution, especially of industrial origin, has been much studied in developed countries, and the relation to chronic obstructive lung disease (chronic bronchitis and emphysema) in cold, damp climates was thoroughly investigated in the 1950s. The degree to which this work is transferable to hot and often dry countries is unclear, and its relevance to acute respiratory infections in the young is still more doubtful.

4.13 The literature on trauma—whether personal violence or road traffic accidents—is massive but tends to either be outside the health field or only concerned with the medical management of trauma. It is a predominantly western literature, and even within the health field there is need for better understanding of how to organize the management of major trauma with very limited health care facilities.

4.14 The literature on occupational diseases is great, and many of the earlier studies from western countries have relevance to the burgeoning and poorly regulated industries of the developing countries. Yet hazards are greatest at the small enterprise and informal sector levels where ignorance is still very great. Field surveys to define the problem are urgently needed in varied developing country cities, and these will likely lead to specific research in search of solutions to particular disease problems, with good hope of success.

4.15 Operational or highly applied research will be of relevance for many of the environmental improvements listed. Sometimes health issues need more emphasis, as in work on improved cooking stoves; in others the key issues concern operation and maintenance, as with garbage collection. In all those areas where enforcement and policing play a major role—occupational safety and pollution control, trauma reduction, food hygiene—issues of organization and prevention of corruption and evasion loom very large.

4.16 Our specific proposals for further research concern the health sector.

The Analysis of Demographic and Health Surveys (DHS)

4.17 The data sets of the Demographic and Health Surveys (DHS) are available at the London School of Hygiene and Tropical Medicine's Centre for Population Studies and other research centers. These surveys are undertaken by Westinghouse, funded by the United States Agency for International Development (USAID), and cover a wide range of developing countries. They cover mortality, morbidity, socioeconomic and environmental characteristics of the household and use of health services. About four of the data sets currently available contain urban samples large enough to analyze the urban data separately from the rural data. An urban sample of at least 2,000-3,000 households would be needed if urban health data were to be disaggregated by, say, socioeconomic status or environmental characteristics. Mexico, Brazil, Indonesia, and Egypt have sufficiently large DHS urban samples to justify further examination. To the authors' knowledge no intra-urban analysis of the DHS data has been undertaken. Secondary analysis of these large, population-based surveys whose quality has been validated is recommended as an effective and efficient way of producing more information on intra-urban differentials in health. Moreover, given the nature of the DHS, these differentials can then be tested for associations with environmental variables such as housing quality, water and sanitation availability. A combination of skills covering demography, epidemiology, health planning, environmental health, and urban health would be needed to get the most out of the analysis of DHS. A brief visit to each country studied would probably be required to ascertain the local interpretations of the categories used, such as the local definition of latrine ownership.

Linkages With Forthcoming Surveys

4.18 Another efficient way to gain more information on the linkages between environmental problems and the health of vulnerable urban groups is to ensure key questions are included in forthcoming surveys to be undertaken for different reasons.

Increasing the Utility of Routine Surveillance Data

4.19 All health care facilities collect statistics on their work, whether accurate or not, and these are usually reported but then ignored. Except for research projects, data on the homes of patients are rarely kept in a logical form though they are often judiciously recorded. In developed countries the addition of a postal code to death certificates has opened up a new area of spatial analysis of data. Something of a similar nature, but more basic, might be used in recording data on patients in urban health care facilities. It may be possible to divide a city into fewer than ten main areas with as many as nine sub-areas of each (though fewer would be preferred). Such an approach to the use of routinely collected data for analysis of intra-urban variation should be explored in a medium-sized but diverse city to see how feasible it is.

Non-formal Occupational Hazards

4.20 Understanding of occupational hazards at the community level in developing countries is minimal. This is especially the case for small-scale industry and the informal sector. Field studies are needed to assess the scale and nature of the health risks in cities of Latin America, Asia, and Africa. An initial study in one or preferably two cities should be supported to provide an initial estimate, develop methodology, and assess the difficulties of such work.

Urban Air Pollution

4.21 Urban air pollution at both area and household levels requires much further understanding. However analyses on extensive air sampling data and studies of domestic air pollution in relation to respiratory infections have recently begun. The area certainly needs more resources for research.

A Possible Model

4.22 We have attempted to create a "model city" of a million people in the third world, with four social/economic/environmental levels, two sexes, and six age groups. For each of these 48 cells and on the basis of any available data and our judgment, we postulated the proportion of the total population, the specific death rate, and so the distribution of deaths. For each cell we then attempted to allocate causes of death, and finally to relate these to environmental changes. But our attempts have revealed the total inadequacy of the data for generating such a model of urban environmental health profiles. We are much concerned lest our guestimates should be used to draw policy conclusions. This would be quite wrong. There are problems both of data adequacy and of the approach. That is not the spirit in which to approach this exploratory modelling. The model appears as Appendix 1.

4.23 Given the inadequacy of existing data sets for developing such a model, field research is recommended to generate the information needed for building urban environmental health profile models in one or two developing country cities.

Epilogue

4.24 To any person who has visited San Diego, Chatsworth House, and downtown New York, let alone the favelas of Rio and the slums of Calcutta and Lagos, the remarkable feature is not the existence of intra-urban mortality differentials but that the human species can survive at all in such a contrasting range of environments. The capacity for adaptation displayed by mankind is remarkable, and so crude a measure as mortality does not adequately reflect the cost of that adaptation. We would therefore caution the reader against use of the measurements of disease for policy beyond their reasonable application. And in our conclusion, we remind the reader of the words of Rene Dubos which begin this report. The designs and goals of planners of urban development should coincide with the reply of Federigo Montefeltro to those who asked the necessary quality of a ruler: *essere umano* (to be human). Health is a necessary but not sufficient aspect of that development of humanity which was the original purpose of urbanization.

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APPENDIX

Deaths in a Model City

A1.1 To facilitate exploration of the environmental health, particularly mortality, aspects of urbanization we have developed a simple and transparent model of a third world city population. Since this is the first stage of such a model it is a static model of mortality; that is, the population distribution is specified and annual rates are applied to it in order to obtain a pattern of deaths by sex, age, and socioeconomic housing group. Causes of death are then added to the death rates, and, from assumptions about the environmental determinants of the medically specified causes of death, it is possible to begin to explore effects of environmental change.

A1.2 Two things became abundantly clear during this elementary modelling exercise. The first is that this is a great oversimplification of only a shadow of reality. The second and more important finding is that there is a total lack of data upon which the model could be based. Not only is there no source of information for a developing country city on age, sex, and economic housing group specific causes of mortality, there are also no data on mortality rates by these categories and almost none on population distribution by age and socioeconomic housing group. In general, by the time data of the type needed are available, the city has ceased to be typical of the third world. The one developing country with relatively good data on cause of death by sex and age is Brazil, but even here there is no socioeconomic housing grouping of data. There appears to be one way to move towards such data without making the task too complex for registration systems. That is to extend the British system of detailed post-coding, as is discussed in this paper. The numbers used in the model are therefore illustrative "guesstimates."

A1.3 The urban model we have used is very basic and is a population model. The population falls into twelve demographic categories—by sex and six age groups. The age groups were selected on the basis of having different health and mortality patterns and also on the way data are usually reported. They comprise infancy (the first year of life), young childhood (from 1 up to 5 years of age, ending on the fifth birthday), the next decade covering the remainder of childhood up to age 15, adult active and reproductive life, 15–44 years, later adult life (45–64 years), and over 65 years. Boundaries in adult life are inevitably arbitrary, and it would be easy to increase the number of age categories. Because the data are so inadequate, we doubt if this would increase understanding.

A1.4 Our model classifies the population into four socioeconomic housing groups: the wealthy and middle classes together, the poorer people in the organized housing sector, those who dwell in shanty towns, and a fourth group of pavement dwellers and those of no fixed shelter. This simple categorization, with environmental health issues in mind, is both a gross oversimplification and yet too complex for available data. We do not see a way to further simplify it. The operational definition of the boundary between the organized sector and shanty towns requires further empirical work, as does the definition of the urban boundary.

A1.5 The combination of sex, age, and socioeconomic housing groups divides the population into 48 (2 x 6 x 4) categories, and each category can have an independent mortality rate and percentage of different causes of death. The classificaton of causes of death can be as complex as

needed—we consider that to exceed twelve categories would be pointless for most purposes and that less would be desirable. Ten categories will give some 500 cells in a table of deaths by cause, age, sex, and socioeconomic category and would require resimplification for use.

A1.6 In constructing the model, in the absence of data by socioeconomic housing category, we specified a relative mortality between socioeconomic groups of the same age and sex, and then constructed a table for converting the mean age-specific and sex-specific rate into rates for each socioeconomic category. Using a first crude age distribution and age-specific death rates, the aggregate values were estimated with the reported Indian urban crude death rate of 9.0 in mind, and the outcome was reasonably close. The detailed age and sex structure within each socioeconomic group was selected on the basis of historical data from various sources.

A1.7 There are two ways in which the differential mortality between socio-housing classes can be put into the model. The first, which is used here in the absence of data for the alternative approach, is relatively unsatisfactory and can easily lead to circular reasoning. It makes overt assumptions about the age-specific mortality ratios between the classes, and then applies them to a separately generated age and class structure of the present urban population.

A1.8 The alternative and preferable approach would be to use empirically determined age-, class- and sex-specific mortality rates as primary data. We were not able to locate such data, and in the case of pavement dwellers are fairly confident that the data do not exist. Thus our model serves chiefly, as do most epidemiological models, to point out the gaps in our knowledge.

A1.9 The model is now described. We have distinguished between primary assumptions and consequences; and selections will be in bold type and parameters derived from those assumptions in ordinary type. Matrices, or tables, are designated by a bold, underlined letter. The reader can thus easily distinguish assumptions from consequences and see where he or she can respecify the values in the model. Although the first version of the model was calculated manually, a computer version is in preparation. This will enable anyone to respecify the parameters and rapidly recompute the whole model. Our own choice of data is the most appropriate we can devise today, but the data are wholly inadequate, as we are well aware, and should gradually be replaced with more appropriate material. For the present, we have stopped short of elaborating causes of death.

Primary Specifications of Model Parameters

(a) City size: one million people: **A**, (b) Socioeconomic structure: **B**

Four categories; proportion of city population in each category as shown below:

Category	Share of City population		
Wealthy and middle class	**15%**	**R**	**.15**
Workers in organized housing	**30%**	**W**	**.30**
Squatter settlement inhabitants	**50%**	**S**	**.50**
Pavement dwellers	**5%**	**P**	**.05**

(c) Sex ratio of population within each socioeconomic category:

In this primary model we have selected equal numbers of each sex but any proportion of each sex may be selected.

C: Proportion of Sexes in Each Category

Socioeconomic Category	Percentage of Males	Percentage of Females
R	0.5	0.5
W	0.5	0.5
S	0.5	0.5
P	0.5	0.5

However, the model allows separately for variation in age structure by sex.

(d) Proportionate age distribution of the population within each of the eight socioeconomic and sex categories

In D these are given as a proportion of the total population of that category and have a heterogeneous origin. They are derived from the following sources:

R	Montreal total, 1966	from Keyfitz
W	China, 1953 rounded	from World Bank
S	Sri Lanka 1967	from Keyfitz
P	Jakarta, 1961	from Keyfitz

They are obviously open to amendment on the basis of more relevant data, and have peculiarities due to local events of past history, but it seemed better to borrow the distributions above rather than to use invented or heavily doctored data.

(e-h) Age, sex, and socioeconomic group-specific mortality rates

These could have been directly specified but were not. Rather, a mean age-specific mortality for the city is specified: E. Initial data from Porto Allegre in Brazil and China at several periods were used to provide guidance, and levels were taken to give a final crude death rate above 8 and below 20.

The relative mortality of each socioeconomic group, by age and sex, was then specified as a ratio to that of the R Group, wealthy plus middle class, on the basis of our reading of the literature. Many arbitrary decisions had to be made.

Differential mortality ratios

The weighted average for each category in matrix F is calculated on the basis of the proportion of the overall population in each of the four socioeconomic categories (for example, males aged 1-4, weighted average = 1 x .15 + 1.5 x 3 + 4.0 x 5 + 8 x 0.05 = 3.0). Matrix G is then derived by dividing each item by the average for that line.

Matrix G is therefore derived from B, the socioeconomic housing structure of the population and F, the differential mortality ratios. The age, sex, group-specific mortality rate then follows by multiplying the relevant elements of G by the age-specific mortality rates E to give the detailed mortality rates in H. Alternatively, the rates in H could be specified directly from data, when H would become primary instead of E and F.

City Population Distribution

The age, sex, group-specific composition of the city population is derived simply by multiplying urban population A by the relevant socioeconomic breakdown B, by the sex proportions C and the result, the proportion in each sex and socioeconomic group, by the relevant age-structure matrix component in D (used as a proportion rather than a percentage) to give table J. For example, the top left-hand element in J is derived as (population) x (proportion wealthy/middle class) x (proportion male) x (proportion aged 0 years) 1 000 000 x 0.15 x 0.5 x 0.02 = 1500. This is the number of wealthy and middle class male infants in the city.

Deaths In the City

The number of deaths in the city each year in each category is obtained by multiplying the corresponding elements of H (mortality rates) and J (population breakdown) to give K.

The present set of parameters gives 9,378 deaths in the city each year, a crude death rate of 9.4 per thousand, which is not unreasonable for one of the poorer third world cities. The distribution of deaths by age group may be shown in a more simplified form in table L, which gives the proportion in each category per thousand of all deaths.

Excess Mortality

The overall picture of mortality may be summarized in table M, where the urban situation is analyzed only by age. The population structure is seen in columns (b) and (c), and the deaths and age-specific rates in (d) and (e) giving an age distribution of deaths as seen in column (f). If, as a result of a variety of environmental and health care improvements as well as other more deep-seated changes, the whole city were to have the age-specific mortality of the present middle class (without change of age structure as yet), then the expected deaths would be as in column (h). Column (j) shows the excess of deaths observed above this preferred situation, and as a rate in column (k). Column (l) indicates the proportionate room for improvement, giving the "excess" death rate as a percentage of the death rate among the middle class. Thus, for infants, in the present model,

2,020 deaths occur annually. If health for all resembled that of the well-to-do, 730 would die each year. So there are 1,290 "excess" deaths, and these are 177 percent of the residual 730 deaths.

In a later version of the model, causes of death will be specified and incorporated into the matrix structure and the environmental relevance of the findings can then be more fully explored.

D: Hypothetical Urban Population: percent age distribution by sex and socioeconomic group

Age	R		W		S		P	
category	M	F	M	F	M	F	M	F
< 1	**2.0**	**1.7**	**3.4**	**3.4**	**3.5**	**3.4**	**3.5**	**3.6**
1-4	**7.1**	**6.5**	**12.6**	**12.2**	**11.9**	**12.8**	**13.9**	**14.1**
5-14	**17.4**	**16.1**	**21.6**	**21.3**	**25.5**	**26.7**	**22.3**	**23.0**
15-44	**47.1**	**45.8**	**43.8**	**43.3**	**42.0**	**42.5**	**51.8**	**50.7**
45-64	**19.9**	**21.3**	**14.8**	**14.5**	**13.3**	**11.1**	**4.4**	**7.1**
65+	**6.5**	**8.6**	**8.3**	**5.2**	**3.8**	**3.5**	**1.1**	**1.5**
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

E: Mean Age-specific Mortality by Age

Age category	Annual mortality/1000
< 1	**60.0**
1-4	**10.0**
5-14	**2.0**
15-44	**3.5**
45-64	**13.0**
65+	**60.0**

F: Differential Mortality Ratios (Relative to wealthy = 1)

	Males					Females				
Age category	R	W	S	P	Weighted for age	R	W	S	P	Weighted for age
< 1	1	1.5	3.5	5.0	2.60	1	1.5	3.5	5.0	2.60
1-4	1	1.5	4.0	8.0	3.00	1	1.5	3.5	5.0	2.60
4-14	1	1.5	10.0	15.0	6.35	1	1.5	4.0	8.0	3.00
15-44	1	1.5	2.0	2.0	1.70	1	2.0	3.0	3.0	2.40
45-64	1	1.0	1.5	1.5	1.28	1	1.0	2.0	2.0	1.55
65+	1	1.0	1.0	3.0	1.60	1	1.0	2.0	3.0	1.60

G: Modified Differential Mortality Ratios (weighted average)

Age	Males				Females			
category	R	W	S	P	R	W	S	P
< 1	.38	.58	1.35	1.92	.38	.58	1.35	1.92
1-4	.33	.50	1.33	2.67	.33	.50	1.33	2.67
4-14	.16	.24	1.57	2.36	.16	.24	1.57	2.36
15-44	.59	.88	1.18	1.18	.42	.83	1.25	1.25
45-64	.78	.78	1.17	1.17	.66	.65	1.29	1.29
65+	.63	.63	1.25	1.88	.63	.63	1.25	1.88

H: Age and Sex-specific Mortality Rates by Socioeconomic Housing Groups

Age	R		W		S		P	
Category	Male	Female	Male	Female	Male	Female	Male	Female
< 1	22.00	22.80	34.80	34.80	81.00	81.00	115.20	115.20
1-4	3.30	3.30	5.00	5.00	13.30	13.30	26.70	27.70
5-14	0.32	0.32	0.48	0.48	3.14	3.14	4.72	4.72
15-44	2.07	1.47	3.08	2.91	4.13	4.38	4.13	4.48
45-64	10.24	8.45	10.14	8.45	15.21	16.77	15.21	16.77
65+	37.80	37.80	37.80	37.80	75.00	75.00	112.81	112.81

J: City Population Distribution by Socioeconomic Group, Sex and Age Category

Age	R		W		S		P		
Category	Male	Female	Male	Female	Male	Female	Male	Female	Total
< 1	1,500	1,275	5,100	5,100	8,750	8,500	875	900	32,000
1-4	5,325	4,875	18,900	18,300	29,750	32,000	3,475	3,525	116,150
5-14	13,050	12,075	32,400	31,950	63,750	66,750	5,575	5,750	231,300
15-44	35,325	34,350	65,700	65,000	105,000	106,250	12,950	12,675	437,350
45-64	14,925	15,975	22,200	21,750	33,250	27,750	1,850	1,775	139,475
65+	4,875	6,450	5,700	7,800	9,500	8,750	275	375	43,725
Σ Population	75,000	75,000	150,000	150,000	250,000	250,000	25,000	25,000	1,000,000

K: Deaths Per Year in the City by Socioeconomic Group, Sex, and Age Category

Age	R		W		S		P		
Category	Male	Female	Male	Female	Male	Female	Male	Female	Total
< 1	34.20	29.07	177.48	177.48	708.75	688.50	100.80	103.68	2,019.96
1-4	17.57	16.09	94.50	91.50	395.68	425.60	92.78	94.12	1,227.84
5-14	4.18	3.86	15.55	15.34	200.18	209.60	26.31	27.14	502.16
15-44	73.12	50.49	202.36	189.44	433.65	465.58	53.48	55.52	1,523.64
45-64	151.34	134.99	225.11	183.79	505.73	465.37	28.14	29.77	1,721.24
65+	184.28	243.81	215.46	194.84	712.50	656.25	31.02	42.30	2,280.46
Σ Population	464.69	478.31	930.46	952.39	2,956.49	2,910.70	332.53	352.53	9,378.00
Rate: ‰	6.20	6.38	6.20	6.35	11.83	11.64	13.30	14.10	9.40

L: The Distribution of One Thousand Deaths by Age-sex-housing Category

Age	R		W		S		P		
Category	Male	Female	Male	Female	Male	Female	Male	Female	Total
< 1	4	3	19	19	76	73	11	11	216
1-4	2	2	10	10	42	45	10	10	131
5-14	< 1	< 1	2	2	21	22	3	3	53
15-44	8	5	22	20	46	50	6	6	163
45-64	16	14	24	20	21	50	3	3	184
65+	20	26	23	31	46	70	3	5	254
Σ Population	50	50	100	102	315	310	36	38	1,001*

* Rounding Error

M: Calculation of Excess Mortality by Age Category (all death rates are per thousand)

(a) Age Category	(b) Population (from J)	(c) Percent population	(d) Deaths (from K)	(e) Death rate (d)/(b)	(f) Percent of Deaths
< 1	32,000	3.2	2,020	63.12	21.5
1-4	116,150	11.6	1,228	10.57	13.1
5-14	231,300	23.1	502	2.17	5.4
15-45	437,350	43.7	1,523	3.48	16.2
45-64	139,475	14.0	1,724	12.36	18.4
65+	43,725	4.4	2,381	54.44	25.4
Total	1,000,000	100.0	9,378	9.37	100.0

M: (continued)

(a) Age Category	(g) R Death Rate (from H)	(h) R Rate Deaths expected (b)x(g)	(i) Excess deaths (d)-(h)	(j) Excess Death Rate (e)-(g)	(k) Excess deaths as a percentage of R Rate Deaths (k)/(g)
< 1	22.80	730	1,290	40.31	177
1-4	3.30	383	845	7.28	221
5-14	0.32	74	428	1.85	578
15-44	1.77	774	749	1.71	97
45-64	9.30	1,297	427	3.06	33
65+	37.80	1,653	728	16.65	44
Total	6.29	4,911	4,467	4.47	91

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