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The Agency for International Development commissioned the Smithsonian Institution's Office of International and Environmental Programs to undertake a case study of a developing-country city which had experienced rapid growth in order to develop the basis for urban environmental guidelines. In 1971-1972 a case study was made of Seoul, Korea, whose 6.3 million population has been arrived at with a doubling rate of approximately ten years. That case study is summarized in Part III of this document.

The urban environmental problems for which guidelines have been formulated are based largely upon the problems studied in Seoul. Interpretations and recommendations developed by nine scientists and engineers who participated in the case study were translated to the extent possible into guidelines of wider applicability .

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The Environmental Impact of Rapid Urbanization:

Guidelines for Policy and Planning

Based Upon a Case Study of Seoul, Korea, in 1972 and 1973

By Peter H. Freeman

Office of International and Environmental Programs
Smithsonian Institution
Washington, D.C. 1974

Common prudence argues that the serious impacts of pollution being experienced in the cities of industrialized nations should to the extent possible be minimized or avoided in developing-country cities just beginning to experience these impacts. However, the unprecedented rapidity of urban growth rates in developing countries and the condition of underdevelopment combine to create an apparent dilemma. Urban air and water pollution, congestion, crowding, and the resultant public health impacts are emerging with astonishing rapidity in developing-nation cities at the same time that a measure of material prosperity is being attained. However, cities contribute to national financial resources, and there are infinite demands on these from less developed sectors and regions. Thus, developing nations apparently cannot yet afford the "luxury" of investing in urban environmental quality. Nevertheless, if urban growth does contribute to the deterioration of the urban environment, it behooves international and national development agencies to adopt policies and guide investments in cities so as to minimize avoidable impacts. Guidelines are needed for such policies and they must be based upon the unique reality of rapidly growing cities in the developing nations.

With this need in mind the Agency for International Development commissioned the Smithsonian Institution's Office of International and Environmental Programs to undertake a case study of a developing-country city which had experienced rapid growth in order to develop the basis for urban environmental guidelines. In 1971-1972 a case study was made of Seoul, Korea, whose 6.3 million population has been arrived at with a doubling rate of approximately ten years. That case study is summarized in Part III of this document.

The urban environmental problems for which guidelines have been formulated are based largely upon the problems studied in Seoul. Interpretations and recommendations developed by nine scientists and engineers who participated in the case study were translated to the extent possible into guidelines of wider applicability.

Certain characteristics of Seoul limit its representativeness of developing-nation cities. It is in a temperate rather than subtropical or tropical zone. It is located on a river (the Han River) rather than on a coast and does not possess a major port with concomitant coastal water pollution and coastal marine resource management problems. Its growth pattern has been determined in part by the 35-year period of Japanese occupation (1910-1945) and by the devastating and traumatic effects of the Korean War. Yet, notwithstanding these geographic and historical differences, Seoul has experienced air and water pollution, congestion, and squatter slum problems which are virtually generic to rapidly growing cities in developing nations. Problems characteristic of cities in tropical climates or on coasts

have not been neglected. Guidelines based upon some of these problems have been included in the text.

In the drafting of these guidelines it was the urban planners and policy makers of developing countries who were viewed as the foremost audience. It was assumed that if guidelines were useful to them, they would also be useful to international development assistance organizations. Indigenous solutions must be evolved for urban development and urban environmental management in developing countries to a greater degree, perhaps, than any other development situation. Cities constitute on the one hand a synthesis of a society's history, and on the other they are the ultimate expression of a society in transition. At the same time our understanding of urban dynamics is still very limited. Development models for urban systems do not yet exist for developing or developed countries. Techniques for predicting urban growth are rudimentary and limited in scope. No single solution or combination of solutions can be identified as constituting the "best fit" for a developing-country city. There is no authoritative source, therefore, to which developing nations can turn for comprehensive guidance. They must test and evolve their own urban policies and programs and benefit to the extent possible from the experience of other cities.

The formulation of widely applicable guidelines, based upon a single case study, strains the limits of logic and scientific method. Every attempt was made to develop accurate definitions and useful conclusions from the Seoul case study on a level of approximation which would retain their validity but not obscure their relevance to other cities by excessive attention to detail. The Seoul case study summary (Part III), in which relevant details are presented, therefore comprises an important adjunct to the guidelines.

The basic philosophy underlying these guidelines is that urban environmental problems can be managed and that costly impacts can be minimized or prevented, even in a situation of accelerated growth. However, this will require the resolution to attain the best future urban environment possible, and the determination to formulate effective policies, plans, and actions to attain that goal.

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I. INTRODUCTION

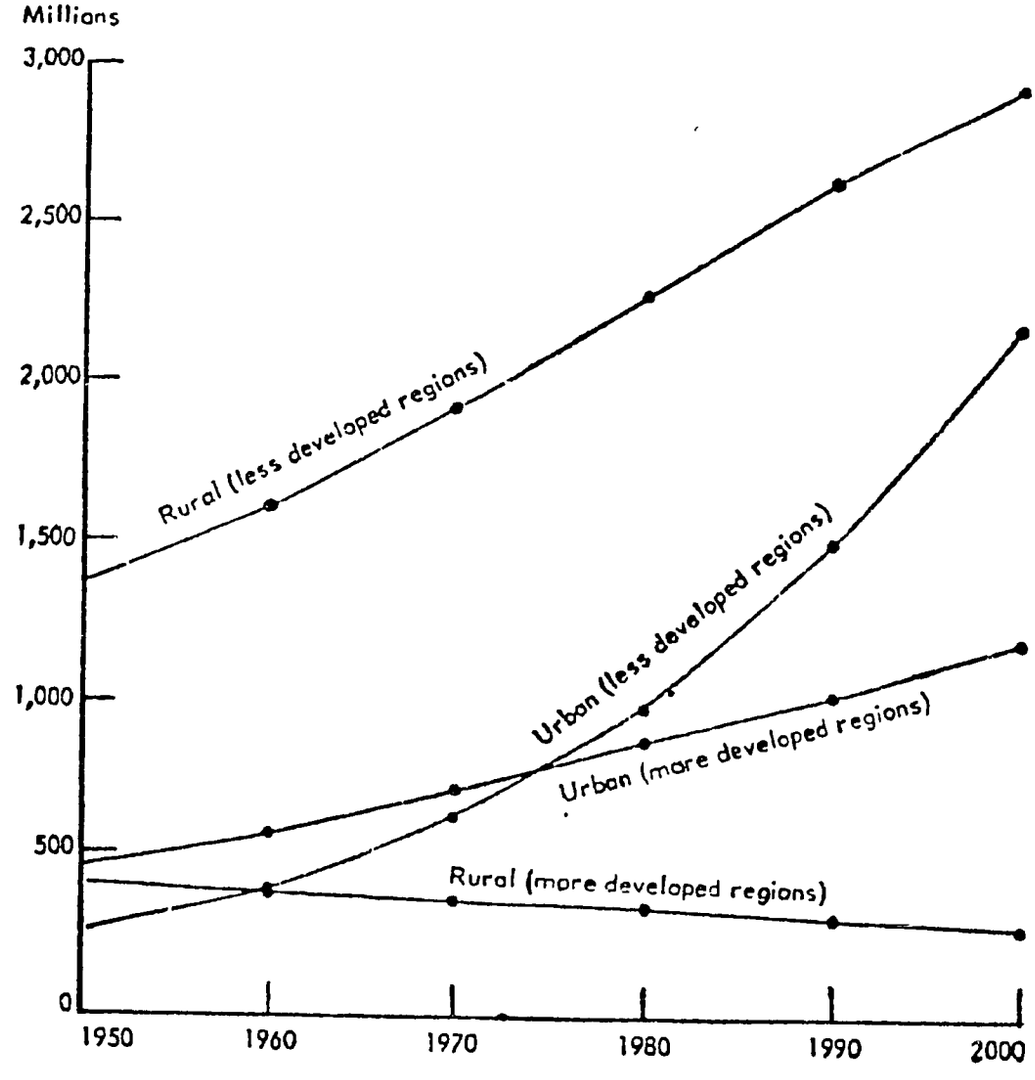
During the remaining 26 years of this century the world population will have increased, according to best estimates, from 3.86 billions (mid-1973) to 6.49 billions. Most will be urban dwellers. The urban population for 2000 is projected to be almost as large as the total world figure for 1973. Today urban areas harbor only 30 percent of the total population, but the populations of the cities are growing roughly three times as fast as rural populations. The 3.6 billion urban inhabitants in 2000 will represent over 60 percent of the world's total. Since less developed countries manifest greater natural increase in population, as well as greater rates of urbanization than developed countries (Davis, 1972), the phenomenon of rapid growth will be acutely felt in their existing and future cities during the next two and a half decades. Their high growth rates have no parallel in the experience of developed-nation cities, hence the experiences of these cities in coping with urban management problems are of only limited use as models.

Development through industrialization is both impelled and compelled by the growth of cities. During the transformation from an agricultural to an industrial economic base, it seems inevitable that growing cities will initially exhibit symptoms of underdevelopment, particularly sprawling squatter settlements which typically house one out of three urban inhabitants, and, in extreme cases, two out of three. Many, but not all, urban environmental problems in developing countries are generated by this condition of underdevelopment, even though city sizes may be comparable to those of developed, industrialized nations. It is not surprising, for instance, that squatter settlements lack adequate water supplies and wastewater treatment, and that serious public health problems associated with urban water pollution are virtually universal in developing countries. Even the better-off citizens lack adequate water supply in many cities of the developing world.

In older cities traffic congestion is aggravated by narrow streets not designed for automobiles and trucks, which must furthermore compete with cheaper modes of conveyance such as bicycles, motorcycles, hand- or animal-drawn wagons, and the like. In tropical climates, where buildings do not require insulation from cold, exposure to noise pollution in congested areas tends to be higher than in cities in colder climates. Food sanitation and conservation of perishable foods represent greater problems in hot, humid climates than in the cooler climates of higher latitudes which characterize most developed-country cities. Added to these relatively unique problems are air and water pollution familiar to any urban dweller.

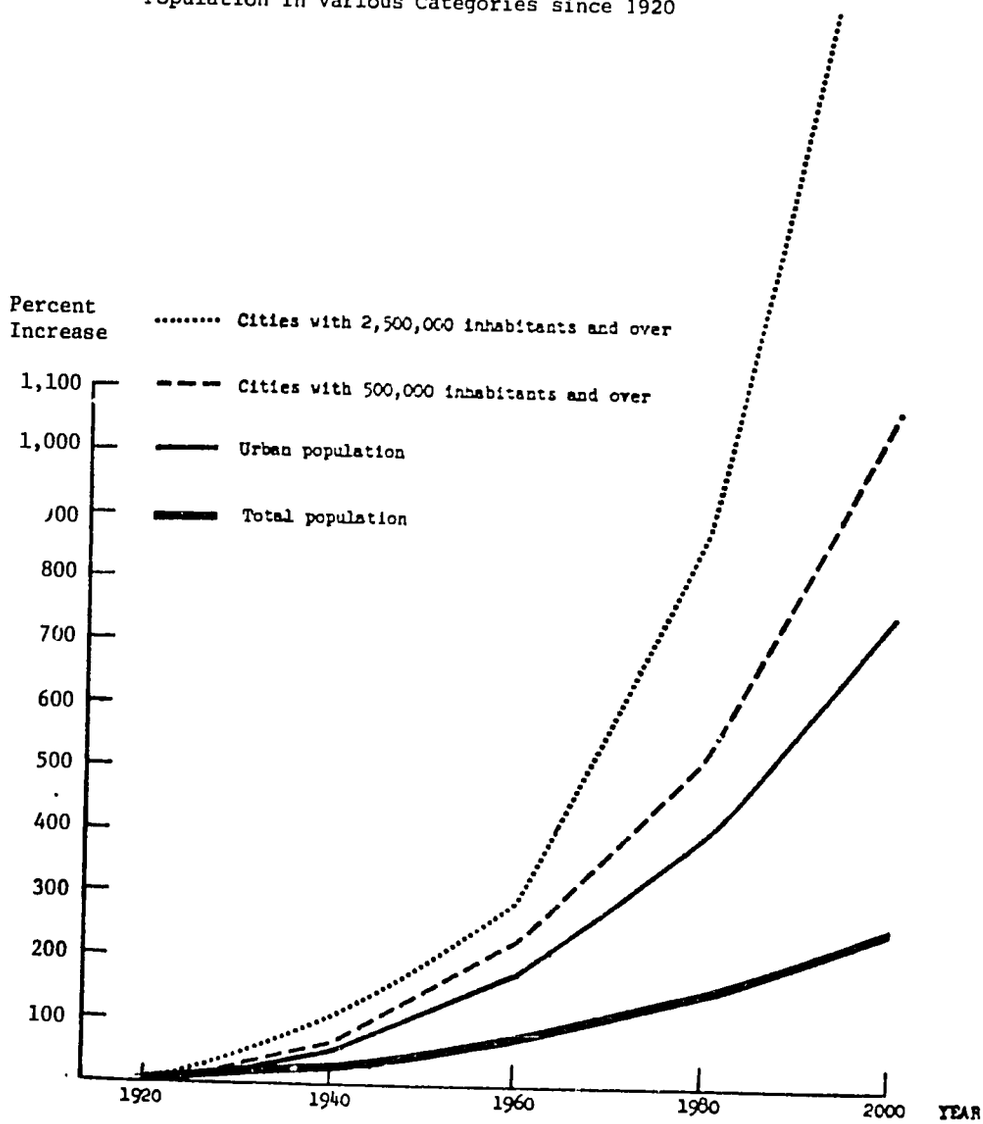
If the cities of developed nations are only beginning to struggle out from under mounting problems of environmental deterioration, and at costs that are considered high even

Figure 1 Urban and Rural Population, in More Developed and Less Developed Regions, 1950-2000



Source: Ciborowski, 1972.

Figure 2 Growth of Total World Population and Urban Population in Various Categories since 1920



Source: Ciborowski, 1972.

for prosperous societies, the environmental problems of rapidly urbanizing cities in the poorer, developing countries take on phenomenal proportions. Yet they must ultimately be managed if cities are to contribute to a society's development and become viable environments in which the goals of material and social progress are to be enjoyed by this and the next generation.

The future environments of rapidly growing cities will depend largely on goals, policies, and plans made in the 1970's as well as on patterns that have already been established. Many cities of today with 100,000 inhabitants are very likely to number 500,000 by the year 2000; cities with 500,000 may well grow to over 2.0 million in the same period. What decision can be taken at the early stages of urban growth to ensure the best human environment as economic development goals are achieved, whether in 1985 or 2000?

Guidelines for preserving the environments of rapidly growing cities in developing countries are clearly needed. This document attempts to set forth such guidelines, albeit tentative ones. The guidelines are based largely upon a case study of Seoul, Korea, whose ten-year doubling period has resulted (by 1973) in a population estimated at 6.3 million. While no city is typical, many of Seoul's environmental problems will be familiar to other cities of Asia, and its problems of squatter settlement, central city congestion, water supply, and wastewater treatment are virtually generic to all developing-country urban centers.

A. OBJECTIVES

The objectives of this monograph are to illustrate the environmental impacts of rapid urban growth with reference to a case study of Seoul, Korea, as well as to relevant examples from other large cities in the developing world. Secondly, guidelines for policy, planning, and monitoring are set forth to assist responsible authorities in growing cities to anticipate environmental and related problems and plan for their solution and management in a timely way. The guidelines are especially directed to cities whose urbanization has not advanced to the point that major decisions have already been made on large-scale infrastructural technologies, whose physical plans are still tentative and flexible, and whose slums or squatter settlements have not yet created the need to take emergency or remedial measures. It is intended that these guidelines will assist in the formulation of policies and plans that will help to prevent unmanageable environmental pollution or deterioration and ultimately to achieve a healthy and manageable human environment. The guidelines will also be useful to larger cities, to the extent that they emerge from the analysis and evaluation of a large city. However, in those large cities where serious forms of pollution and congestion have already emerged, remedial action will necessarily be constrained by the high

costs of modifying existing patterns, which in turn will compel carefully designed studies of technically and economically feasible alternatives.

B. ANTECEDENTS

The phenomenon of world urbanization and its relationship to population growth and development have been surveyed by several authorities, including Davis (1969 and 1972), the United Nations (1969), and the International Urbanization Study Group of the Ford Foundation (Ford Foundation, 1972) and Weitz (1973). Viewpoints and results of studies by many scholars have been collected and published in a volume edited by Gerald Breese (1969). Problems of developing-nation cities have been surveyed by the World Bank (1972) and the U.S. Agency for International Development (USAID, 1972a and 1972b), both of which are evolving policies and programs for assistance in urban development.

The environmental problems of developing-country cities have only recently been examined in most regions of the world. Considerable documentation of these problems was developed for the 1972 United Nations Conference on the Human Environment, especially for the human settlements agenda item of that conference. Urban environmental problems were in many cases seen as tangential or integral to other agenda items such as natural resources management and development and the environment.* The World Health Organization has carried out numerous surveys of specific health problems associated with environmental changes. Much of this work is summarized in *Health Hazards of the Human Environment* (WHO, 1972).

Unmanageable urban growth in Latin America has preceded urbanization in Africa, the Middle East, Oceania, and parts of Southeast Asia. Previous to the UN 1972 Conference, the serious environmental problems being experienced in Latin America's primate cities had been reviewed in several regional meetings, including ones sponsored by the Pan American Health Organization (PAHO, 1970) and the Organization of American States (OAS, 1971). Numerous individual scholars, from the developed as well as the developing world, also have studied various aspects of the problems of rapid urban growth, especially squatter settlements, rural to urban migration, public health, and, more recently, water supply, water pollution, and air pollution. However, comprehensive reviews of the total environment of developing-nation cities have not been undertaken, and even in the developed countries this work remains to be done.

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*The reader is referred to the bibliography of documents that was produced for the UN Conference on the Human Environment (UN, 1972).

The methodology and conceptual framework for an urban environmental assessment is, in fact, a major challenge that urgently needs research attention.

The Seoul case study represents a first attempt at such an assessment. The study experience indicated that, among other things, a survey method must be developed for collecting and interpreting data which reveal economic and social costs of environmental deterioration in order to enable an assessment which can be employed in over-all economic and social planning. Also, special attention must be focused on manpower and institutional needs for environmental management in order to permit the formulation of realistic recommendations.

Urban environmental guidelines focused on the rapidly growing developing-country city have not hitherto been attempted. However, environmental guidelines developed by the World Bank in consultation with USAID (World Bank, 1973), intended to orient preinvestment studies of various kinds of capital development projects, bear directly on many aspects of urban environmental pollution, including major types of industry, airports, ports and harbors, roads, sewerage, and sewage treatment. A separate section of this work treats the subject of air and water quality standards and includes examples of ambient and emission standards pertinent to air pollution.

The U.S. Environmental Protection Agency (EPA) is a source of detailed information on all aspects of air, water, and noise pollution, emission sources and characteristics, pollution control technology, and the impacts of various kinds of pollution. That agency recently published a bibliography (EPA, 1973) of 400 research, environmental protection and technology, ecological research, environmental monitoring, and socioeconomic environmental studies. Other work published by EPA is cited at pertinent places in this work.

In the international arena, guidelines for the assessment of air quality were drafted by the NATO Committee on the Challenges of Modern Society (NATO/CCMS, 1971). The inclusion of Ankara as a case study in that work enhances its value for developing-country cities. For example, domestic heating methods in Ankara utilizing low-quality fuels are a primary source of serious air pollution, which is compounded by unique physical and meteorological conditions. Seoul has similar problems. Wherever applicable, material from antecedent research, reviews, and guidelines has been incorporated into the present document.

C. SCOPE AND LIMITATIONS OF THE GUIDELINES

The unprecedented speed of urban growth in developing countries makes the formulation of guideline statements a tentative exercise at best. Moreover, guidelines based upon the case study of one city are necessary limited to

the representativeness of that city. The case study approach to Seoul should, however, provide sufficient in-depth understanding to enable an evaluation of the guidelines emerging from its experience.

The implications of the world energy situation are of great relevance to future urban environments. The rapid depletion of world energy resources compounded by the failure, to date, to develop feasible alternative technologies is of great significance to future urban patterns and activities. The apparent inevitability of the need to shift to energy-conservative forms of architecture and transportation clearly relates to policy options and strategies for controlling environmental pollution from energy production and consumption.

Energy-conservative technologies in architecture, transportation, and waste recycling are only beginning to be envisaged in the total urban context, but research and study will be intense in coming years. Perhaps the most relevant work for developing-country cities on this subject has been carried out by Richard L. Meier and his students at the University of California at Berkeley. Meier has developed the concept of resource-conserving urbanism and applied it to a study of Bombay, India (Meier, 1972a and 1972b). Although the concept is applied to a city that is already in excess of 6.0 million, it deserves serious consideration by the smaller, rapidly growing cities to whom this document is addressed. No attempt will be made here to assess the relevance of this concept despite the fact that many of the lessons in the Korea experience are applicable to small cities in the process of growth. In this respect they are similar to those of Bombay, India.

Also, it has been beyond the scope of this work to incorporate the considerable amount of thought that has been devoted to alternatives to present city patterns, such as floating cities, or radically different physical space and activities such as the city of Auroville in India (Anon., 1973) and others. Nor is an attempt made to assess the sociological implications of changes in sex roles and the nuclear family structure as these relate to future urban environments.

Finally, under the rubric of urban land use, only open space is considered. An environmental focus on urban land-use policy in general would not be possible without taking into account a constellation of physical, geographic, demographic, political, and socioeconomic variables which tend to occur in unique combinations for different cities. These variables tend to overwhelm any environmental common denominator. It was considered that environmental guidelines for urban land use would be subject to so many qualifications that their value would be doubtful. However, where the various environmental guidelines that have been formulated do influence land use, consideration is given to land-use policy and planning.

An important facet of land use not developed, but which is worth mentioning here, is the competition between urban

and agricultural land uses at the margins of growing cities. Many cities are situated on fertile plains or uplands and their growth will be at the sacrifice of a nation's best soils. The determination of the best use of such prime farmlands, whether for urban growth or agricultural production, must be made at the national level. Explicit recognition of the trade-offs should be incorporated into national development goals and policies.

II. ENVIRONMENTAL GUIDELINES FOR RAPIDLY GROWING CITIES IN DEVELOPING COUNTRIES

The environmental guidelines for urban areas presented here are aimed specifically at rapidly growing cities in developing countries. The guidelines address the context of a developing-country city which is in early stages of rapid growth. The early stage of rapid growth is a critical time at which, on the basis of growth and development projections, major decisions must be made which set virtually irreversible patterns of land use, transportation, water supply, liquid and solid waste disposal, and low-income housing and settlement. Emphasis is therefore placed upon urban environmental policy and planning, basic informational needs, and monitoring and survey efforts. The guidelines assume a desire on the part of urban leaders to prevent, to the extent feasible, those kinds of growth and activities that have generated intractable and costly environmental problems during growth and at later stages of growth.

A. POLICY GUIDELINES

1. *Common Property Resources Policy Guidelines*

Common property resources include the air mantle, water systems, public space, and complex ecological systems. They are scarce in urban areas, despite the "free goods" label traditionally attached to them by economists; they are essential to production and consumption activities; they are not owned by individuals and therefore do not enter market processes; they generally enter production and consumption decisions on a zero-price basis, i.e., as externalities; and they are interrelated so that alterations in one can change another. Their contamination by human, industrial, and other wastes can affect their quality as resource inputs into production (e.g., suspended solids in water clog power-plant cooling water intakes) and can impact adversely on various receptors such as humans, animals, materials, and economic plants. Also, the values of water systems are closely linked to the integrity of their aquatic ecology.

The management of these common property resources hinges on at least two considerations: their specific productive values (e.g., the value of fishing in rivers or estuaries) and their resilience to pollution or alteration (e.g., water can be recycled; open space cannot be physically expanded).

a) *Open Space Policy*

Open space can shape and guide the physical development of a city. It can act as a buffer for noise, incompatible land uses, and, to some extent, air pollution. It is necessary for recreation. It is a key element in achieving an aesthetic city landscape. Open space requirements will vary considerably according to recreational patterns as determined by culture and physical mobility; hence, no standards are suggested here.

A principal policy criterion should be that open space is a resource that cannot be physically expanded, although intensity of use is variable. Once development has begun to escalate real estate prices, the purchase of urban open space from the private market can be prohibitively expensive. The elimination of buildings to generate open space is not a viable proposition. The physical patterns and quality of open spaces in the future city environment depend--perhaps more critically than any other environmental goal--on early policy decisions for land acquisition.

At the earliest stages of a city's growth, physical planning should establish future open space needs for various purposes and use intensities, and the needed land should be acquired and reserved in the public domain. An effective open space acquisition policy at the earlier phases of a city's rapid growth will require a land policy for low-income in-migrants or effective prohibition of illegal settlement if the open spaces are to remain unsettled.

b) *Water Policy*

Inadequate, low-quality water supply is symptomatic of most developing-country cities, as is the almost universal lack of water-carriage sewerage systems. The World Health Organization estimates that in 1971 almost one-half of developing-country urban dwellers lacked water supply service of any kind; 26 percent used public standpipes; and only 25 percent had household or courtyard service. Loss of water in the distribution system is typically high in developing-country cities--40 percent or more in Seoul in 1970 (Seoul Metropolitan Government, 1971).

Pollution of the water supply at the source and in the distribution system is an increasing problem in larger cities, and Seoul is not an extreme case. In Buenos Aires, MPN* coliform counts of 240,000 per 100 ml. were measured

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*Most probable numbers. Numbers of coliform are not usually counted in water sample analysis; rather, they are derived statistically. Coliform may include fecal coliform of human or animal origin; thus, they are an indirect indicator of the probable presence of disease pathogens.

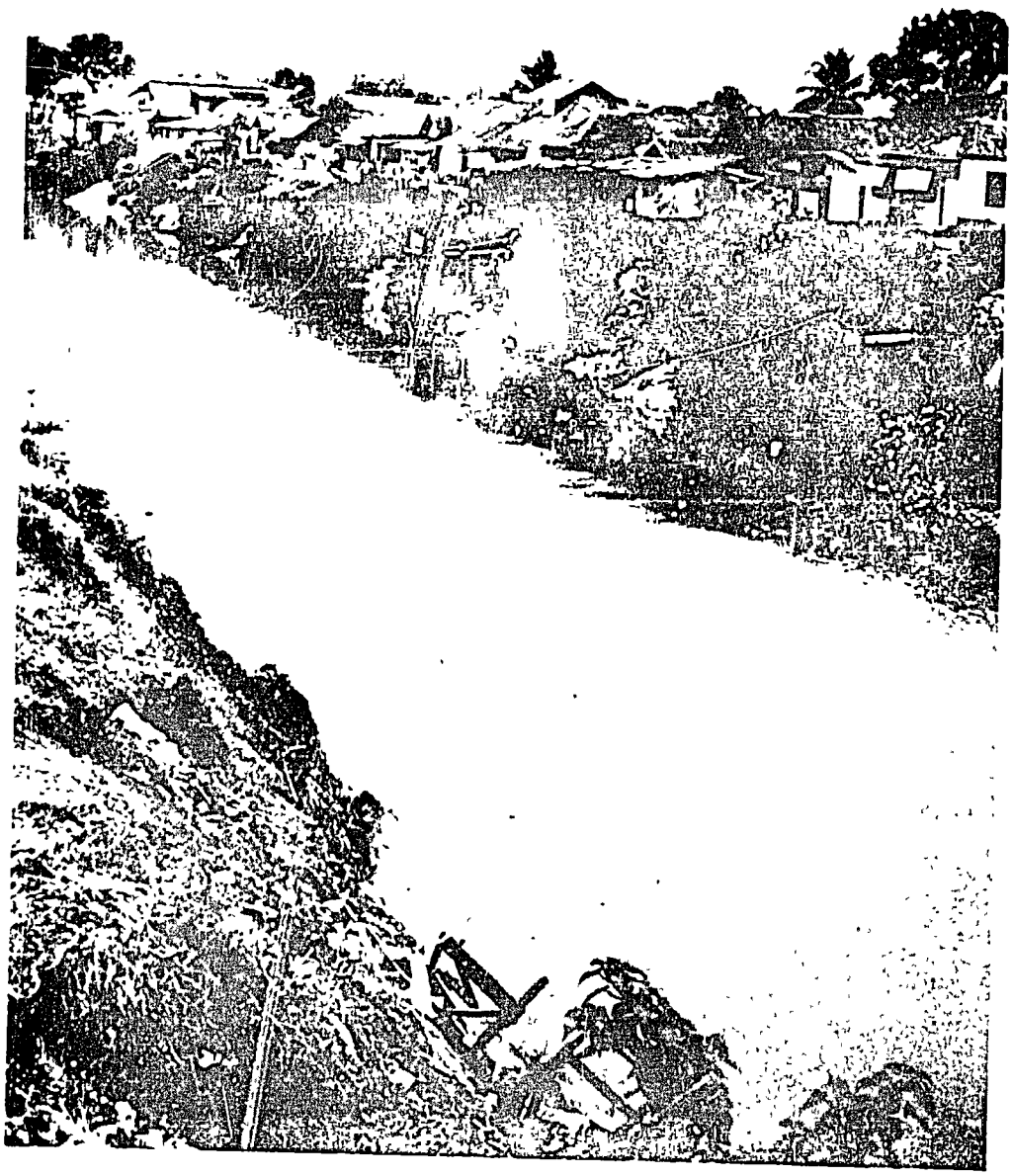


Plate 1. Major drainage canal, Jakarta. Direct disposal of human and other wastes into such drainage canals threatens public health and may entail costs for downstream uses of the water.

at one intake in 1970 (OAS, 1971). By comparison, coliform counts of 10,000/100 ml. have been judged as permissible in withdrawal points for public water supplies in the U.S.A., while less than 100/100 ml. is considered desirable (Federal Water Quality Control Administration, 1972). Permissible and desirable limits for fecal coliform counts are recommended to be one-fifth as much as general coliform counts. In its publication *International Standards for Drinking Water* (WHO, 1971), the World Health Organization does not recommend standards for coliform or fecal coliform counts at raw-water intakes.

The serious public health hazards created by leaky distribution systems susceptible to contamination as well as by deficient supply and wastewater collection and treatment constitute a priority problem for developing-country cities. International development assistance agencies such as the World Bank, the Inter-American Development Bank, the Pan American Health Organization, and USAID increasingly are financing water supply and sewerage systems in larger cities of developing countries.

A principal policy criterion for this common property resource is the need to prevent contamination of the drinking water supply at the source and in the distribution system. Another principal criterion is the prevention and control of pollution by city wastewaters of receiving waters. Where domestic water intakes are located on rivers downstream from wastewater discharge points, as is the case in Seoul, the two criteria are of equal priority. However, to the extent that water-treatment methods can rectify a certain degree of pollution or undesirable quality such as suspended solids, organic matter, turbidity, and odor, a certain amount of some kinds of pollution at water source may be seen as tolerable.

In Seoul, as in most other developing-country cities, priority has been given to extending the distribution system and increasing the amount of water distributed, while treatment of wastewaters has been postponed. The consequences of this policy will have some impact on downstream users of water, or at least on downstream aquatic resources, while, at worst, safety of the urban water supply may be jeopardized.

If it is assumed that a certain level of water pollution of receiving waters is inevitable or tolerable, such assumption should take into account the various kinds of pollutants and their tolerable concentrations. High levels of organic pollution may be reversible, but there should be no flexibility in permitted levels of heavy metals or other nonbiodegradable substances such as polychlorinated biphenyls. Furthermore, such pollutants are primarily from specific industries. It is easier to administer their prevention and control than to control the organic pollutants from thousands of residences in a city.

If short-term "reversible" pollution generating high BOD (biological oxygen demand) and COD (chemical oxygen demand) is to be permitted, based upon the economics of

pollution control or treatment of municipal wastes, levels should be set in full awareness of possible production losses or public health hazards created thereby in downstream, or underground, receiving waters. Minimum quality levels should be set for various types of downstream uses in order to establish limits to such pollution. Appropriate public safety measures should be provided and monitoring should be carried out. Appropriate compensatory measures should be anticipated to cover losses or costs to persons who would be adversely affected by expected pollution of receiving waters.

The human exposure factor and values of receiving waters should be paramount considerations in the formulation of a wastewater treatment policy. Since, generally speaking, both factors rank quite high in developing countries, urban water supply should not be extended without providing for the collection and treatment of wastewaters. Supply and wastewater treatment are dealt with separately below, but only for purposes of facilitating the discussion.

i. *Drinking water supply and distribution*

The principal criteria for policy formulation should be:

1) Requirements for protection of the supply at the source and in the distribution system. Public health criteria are fundamental and should include maximum feasible protection in the system from disease pathogens and toxic substances. Standards for drinking water (Table 3) have been recommended by the World Health Organization (WHO, 1971). Bacterial diseases that can be transmitted in water are shown in Table 1; limits recommended by WHO for toxic substances are summarized in Table 2.

2) Present and foreseeable quality of the supply and its vulnerability to pollution from urban or rural sources.

3) Long-term supply and demand projections based upon population and other growth rates. Such projections should be estimated on the high side.

The development of a water supply and distribution system must realistically project the contamination of the system by wastewaters, especially if these may be polluted by bacteria, viruses, parasites, or toxic chemicals. If there are no alternative sources of water supply, the costs of treating increasingly polluted water at the raw-water intakes may become very high. Policy should stress the construction of tight distribution systems and the avoidance of back-pressure in the systems as a consequence of excessive demand (e.g., extensions of the system in excess of its capacity). Also, it should not be assumed that treatment technology can successfully cope with all pollutants at the supply point. Although technically possible, the money needed for additional treatment would be better spent earlier for better water pollution control through wastewater treatment.

Table 1 Bacterial Diseases Capable of Being Transmitted through Contaminated Water or Food Prepared with Such Water

Disease	Causative organism
Cholera	*Vibrio cholerae*, including biotype El Tor
Bacillary dysentery	*Shigella* spp
Typhoid fever	*Salmonella typhi*
Paratyphoid fever	*Salmonella paratyphi* A, B & C
Gastoenteritis	Other *Salmonella* types, *Shigella*, *Proteus* spp, etc
Infantile diarrhoea	Enteropathogenic types of *Escherichia coli*
Leptospirosis	*Leptospira* spp
Tularaemia (rarely)	*Pasteurella* (*Brucella* or *Francisella*) *tularensis*

Source: WHO, 1972, p. 52.

Table 2 Tentative Limits for Toxic Substances and Some Specific Substances that May Affect Health

Substance		Upper limit of concentration (mg/litre)
Toxic substances [1]		
Arsenic	(as As)	0 05
Cadmium	(as Cd)	0 01
Cyanide	(as CN)	0 05
Lead	(as Pb)	0 1
Mercury (total)	(as Hg)	0 001
Selenium	(as Se)	0 01
Specific chemical substances that may affect health		
Nitrates	(as NO_3)	45
Polynuclear aromatic hydrocarbons (PAH) [2]		0 0002
Pesticides		
Insecticides		No limit specified. The concept of acceptable daily intake (ADI) serves as a guideline for toxicological evaluation
Herbicides		
Fungicides		

[1]Based on an assumed daily intake of 2.5 liters of water by a man weighing 70 kg.

[2]This refers to the six representative PAH compounds: benzo[a]pyrene, benzo[g,h,i]perylene, fluoranthene, benz[e]acephenanthrylene, benzo[k]fluoranthene, and indeno[1,2,3-cd]pyrene.

Source: WHO, 1972, p. 67.

Virus and parasites may be transmitted by polluted water and possibly by water that has been treated with chlorine and is free of coliform organisms. Of particular concern to developing countries is the virus of infectious hepatitis, a disease of global distribution. Although the virus is not yet isolated (WHO, 1972), there is ample epidemiological evidence from widespread outbreaks that it is associated with polluted water and also with shellfish contaminated with sewage effluent. Enteroviruses (including poliovirus), adenoviruses, and reoviruses also are commonly present in polluted waters. The spread of poliovirus by water is rare, however, and other viruses usually are spread through other routes. Cysts of parasites that may be transmitted by polluted water include those of *Entomoeba histolytica*, causative agent of amoebic dysentery (amoebic cysts are relatively resistant to chlorine), *Ascaris lumbricoides* (round worm), and *Trichuris trichura* (whipworm). Various trematodes, including the causative agents of schistosomiasis (*Schistosomiasis japonicum, S. haemotobium, S. mansoni*), ordinarily enter the human body by penetration of the epidermis but they also may be ingested, while others, such as *Fasciola* sp., gain entrance primarily through the digestive tract. However, most trematodes (excluding schistosomiasis) are transmitted to man through fish, shellfish, or on edible plants such as watercress. The eggs of parasites and miracidia of trematodes leave the human host in urine or fecal matter. This underlines the hazards of lake, stream, and irrigation-water contamination by human wastes.

Potable water standards recommended by the World Health Organization are shown in Table 3. The table does not indicate standards for bacteriological water quality. The World Health Organization states that for chlorinated or otherwise disinfected supplies it should not be possible to demonstrate the presence of coliform organisms in any 100 ml. sample of water entering the distribution system. In established nondisinfected supplies, there should be no fecal *Escherichia coli* in 100 ml. If fecal *E. coli* is absent, the presence of no more than 3 coliform organisms per 100 ml. may be tolerated in occasional samples and in supplies which are regularly and frequently tested (WHO, 1972, p. 23).

Underground water may be an important source of water in some cities. If there is an option, deep rather than shallow wells should be employed, especially if wastewater enters natural drainage systems that recharge aquifers or percolates downward to subsurface aquifers. WHO (1972) recommends that water not be used for drinking if coliform counts exceed 10 per 100 ml. Private wells should be lined and covered. They should be dug at depths and locations which preclude contamination from surface waters. This could be controlled by a licensing and permit system.

Table 3 World Health Organization Standards for Potable Water

Constituent	Criterion	
Lead (as Pb)	0 1 mg/l	Maximum allowable concentration
Selenium (as Se)	0 05 mg/l	
Arsenic (as As)	0 2 mg/l	
Chromium (as Cr^{6+})	0 05 mg/l	
Cyanide (as CN^-)	0 01 mg/l	
	Permissible	Excessive
Total solids	500 mg/l	1,500 mg/l
Color	5 units	50 units
Turbidity	5 units	25 units
Taste	Unobjectionable	
Odor	Unobjectionable	
Iron (Fe)	0 3 mg/l	1 0 mg/l
Manganese (Mn)	0 1 mg/l	0 5 mg/l
Copper (Cu)	1 0 mg/l	1 5 mg/l
Zinc (Zn)	5 0 mg/l	15 mg/l
Calcium (Ca)	75 mg/l	200 mg/l
Magnesium (Mg)	50 mg/l	150 mg/l
Sulfate (SO_4)	200 mg/l	400 mg/l
Chloride (Cl)	200 mg/l	600 mg/l
pH	7 0-8 5	(6 5 or) 9 2
$(Mg + Na)SO_4$	500 mg/l	1,000 mg/l
Phenolics	0 001 mg/l	0 002 mg/l
α emitters	10^{-9} c/ml	

Source: World Bank, 1973.

Additional considerations important to the use of groundwater are rate of recharge, likelihood of subsidence, and, in coastal locations, likelihood of saline water intrusion as pumping lowers hydrostatic pressure and saline water displaces fresh water in the aquifer. The possibility of having to recharge aquifers by surface pumping to control subsidence and salinity intrusion should be considered and the costs estimated.

ii. *Industrial water supply*

Various options exist for industrial water supply, and these are influenced by volume available, location and type of industries, and quality required for industrial use (Table 13). However, needs for urban domestic supply clearly have precedence over requirements of high-volume industrial users, such as thermal power plants and the steel industry, the highest volume user. Integrated steel plants require as much as 40,000 gallons of water per ton of finished steel. Clearly, separate water-supply systems will be needed for high-volume users. These systems can be integrated into the industrial zone or individual plant.

Only the best quality water, e.g., drinking water, should be provided to food-processing plants, pharmaceutical industries, central markets, slaughterhouses, and other activities that handle products ingested by humans.

In regions or urban areas with scarce water resources, there should be a policy for encouraging or requiring the recycling of water by large industrial users. The basic technology for technically and economically feasible closed-cycle systems is available and is beginning to be employed in the United States. Recycling can assist in the abatement of industrial water pollution which, in areas with water scarcity (e.g., low-volume river flows), will be a more serious problem than in regions with abundant water and high-flow rivers.

iii. *Wastewater collection, treatment, and disposal*

The principal elements in formulating policy should include:

1) Public health risks, as affected by exposure to contaminants in wastewaters, especially human wastes.

2) Present and projected uses and values of receiving waters, surface or subsurface, and possible impacts of various pollutants.

3) Amount of water available.

4) Physical factors affecting the construction of a collector system.

5) Aesthetics.

6) Economics.

The amount of wastewater generated is directly related to water consumption. In most developing-country cities water consumption is low because most houses do not have individual supply. People may have to walk considerable distances to wells or public water taps to obtain domestic water, especially (but not exclusively) in squatter settlements. Consumption, therefore, is low (15 liters/person/day or less), and wastewater production is low. *The extension of water outlets to more convenient locations (e.g., within a block of a residence) will increase consumption to approximately 75 liters/person/day, and at this point wastewater generation will require attention.* Clearly, the improvement of water supply creates larger volumes of wastewater, and this must be envisaged. It is also obvious that the increase usually will be stepwise rather than incremental.

Public health risks are the priority consideration in the formulation of wastewater policy; consequently, plans should take into account toxic pollutants as well as probable disease pathogens that may enter water and their viability (Tables 1, 2, and 3). Hospital wastewaters sometimes constitute a special threat that is frequently overlooked. If not treated, resistant strains of bacteria may enter the natural water system and could transfer resistance to sensitive strains, with serious public health implications. Further, hospital wastewaters may contain

large amounts of infectious virus material, including the virus of infectious hepatitis. Therefore, *high priority should be placed on the sanitary treatment of hospital wastes to avoid contamination of the general water system.*

Aesthetic criteria may weigh more heavily in cities which draw many international visitors for business or tourism. In practice this has been an important reason for the construction of sanitary sewer-collector systems. The construction of a collector sewer for wastewaters that were previously discharged at several points along the famous beach in the Copacabana District of Rio de Janeiro is a case in point.

The determination of water-quality criteria for various uses within an urban area is a necessary adjunct to policies concerned with wastewater collection and treatment. Criteria are not suggested here. However, useful information may be found in *Water Quality Criteria* (Federal Water Pollution Control Administration, 1972), which addresses the question within the context of the United States. Research published in the English language on the effects of various pollutants and chemicals upon water quality and aquatic life can be found in *Water Quality Criteria Data Book, Vol. 3; Effects of Chemicals on Aquatic Life* (Batelle's Columbus Laboratories, EPA, 1971) and in *Advances in Water Pollution Research* (Jenkins, 1971). It is worth noting that research is very limited on the pollution of tropical and subtropical water systems, either freshwater or marine.

The collection, treatment, and disposal of human wastes are undoubtedly the major considerations in formulating wastewater treatment policy. Methods used will influence decisions for collecting and treating wastewater contaminated with other domestic and urban waste. Most developing-country cities have not adequately dealt with either the human waste or wastewater problem. The World Health Organization has estimated that throughout the developing world a $20 billion investment in urban sewerage works and related water supply improvement will be needed during the Second Development Decade, 1971-1980 (World Bank, 1971). Sewerage systems would cost $11.0 billion of the total.

Several options exist for treating human wastes, but the overriding criterion is protection of public health. The flush-toilet/water-carriage system employed in developed-country cities is considered by most engineers to be the only safe way of collecting, treating, and disposing of human wastes. The water-carriage system, however, is the most expensive method for collecting and treating human wastes. Also, the water-carriage system does not economize water. If water is scarce--and scarcity should be defined in the context of long-term projections of supply and demand--or if capital resources are scarce, "dry" methods (described later) may be perceived as necessary alternatives. Dry methods, however, are characterized by greater public health hazards and would not necessarily prevent water pollution by other wastewaters.

Growing cities situated in regions with abundant water supply can consider the use of the water-carriage system for collecting human and other liquid wastes. Where water is scarce the employment of vacuum sewage systems such as that developed by Aktiebolaget Electrolux of Stockholm, Sweden, may be considered. In that system only 2.8 liters of water are needed for a toilet flush, compared to the 14 to 17 liters used in the standard flush toilet. Water-carriage systems entail the installation of flush toilets or equivalent facilities and the construction of a collector network and associated treatment plants. Like Seoul, many developing-country cities have chosen to forego the cost and limit investment to water supply and distribution.

The delay in construction of a sanitary collector-sewer network and sewerage treatment plant system is economically attractive only in the short term for a city about to undergo rapid growth but which plans such a system. *While experience in already large, developing-country cities indicates that the lack of sewers and sewerage treatment is in fact tolerable, or at least has had to be tolerated, the cost of installing sewage systems in already built-up cities is high.* Added to the direct costs of construction materials and equipment are the indirect costs of traffic congestion in construction areas and the higher costs of land (if public rights-of-way do not exist) due to appreciation of real estate because of urban buildup. If incorporated as integral components into a "sites and services" approach to urban housing and land development, sewerage infrastructure costs may be offset by savings in housing construction (World Bank, 1972, page 47). Cross-sectoral planning and cost-benefit analysis would be required to assess the advantages of that approach. (More is said on this in connection with policy guidelines for the squatter settlement problem discussed later.) In any case, it is inevitable that, at some point, wastewater-collection infrastructure will be necessary. The collection and treatment of all forms of liquid wastes, including human wastes, in a single system will have obvious economic and technical advantages.

The Seoul case study suggested how interim solutions may be used in an already large city to provide limited sewage treatment without entailing the costs of sewer construction and conversion to flush toilets. Urban wastewaters, including some human wastes, enter directly into the smaller streams that drain Seoul. It was decided to treat the entire flow of one of these highly polluted streams before it flowed into the Han River. The objective was to protect downstream raw-water intakes for the city's drinking water supply. A sanitary collector-sewer system was not absolutely necessary to accomplish this objective, so the costs of such a system were thereby avoided. This solution has the disadvantage, however, of uncontrollable fluctuations in stream-flow rates and volumes because storm

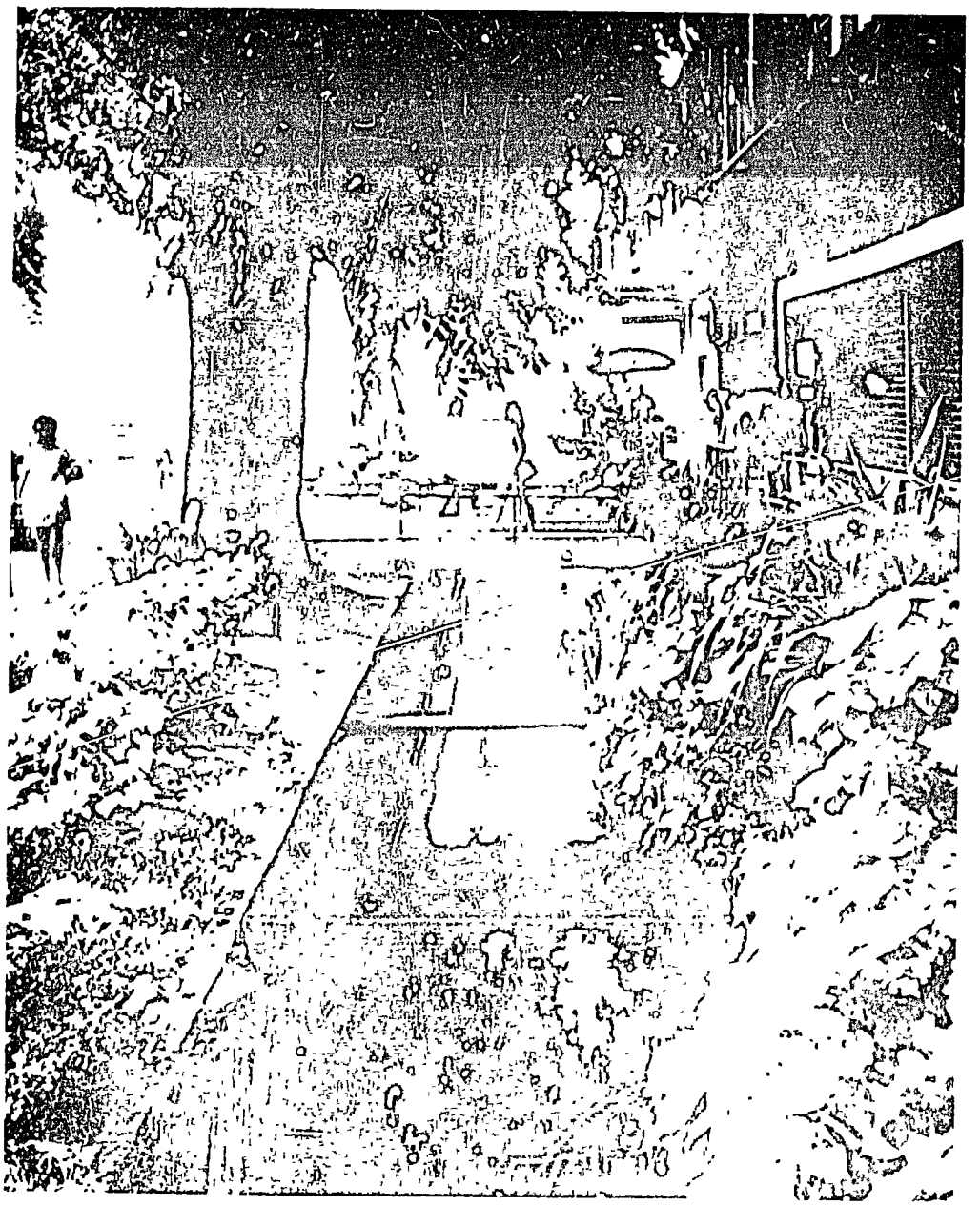


Plate 2. Open, concrete-lined drainage canal, Singapore. In many cities such canals drain stormwaters, domestic wastewaters, and not infrequently human wastes. Canals such as these eventually are paved over as cities formalize and improve wastewater drainage systems imposed on the natural drainage pattern.

run-off is not separated from wastewater run-off. Therefore, stream-flow during peak run-off periods will exceed the capacity of the treatment plant and full treatment will not be possible. Also, the recreational and aesthetic amenities of those streams that are allowed to become open sewers will be sacrificed. Such streams can be paved over gradually and converted into a formal sewer network superimposed on the natural drainage pattern. This is being done to some extent in Seoul as well as many other developing-country cities, but the aesthetic and recreational values of such streams are permanently foreclosed.

As an alternative to the water-carriage system, human wastes can be collected in cesspools and transported by truck to fermentation basins (as has been the practice in Seoul and other Asian cities) or to sites where biological decomposition by various methods can be carried out. The primary considerations are that transport be sanitary and that temperatures generated in decomposition be sufficiently high and sustained to kill all disease pathogens and parasite eggs. The end product--organic sludge or compost--can be used for conditioning and fertilizing soil, if economical.

In Seoul, this alternative solution has not proved effective in controlling water contamination because of inevitable spillage in handling, insufficiently high temperatures in fermentation, and the impossibility of collecting all human wastes in this manner--especially in squatter settlements. These problems can be remedied to some extent. "Sanitary" composting (by generating temperatures of at least 155°F. or 67°C.) could be employed to reduce the hazard of parasite contamination of the end product. Truck-mounted vacuum collection could reduce the spillage problem associated with manual removal of excreta from cesspools. And all residences, including those in low-income neighborhoods and squatter settlements, would have to be serviced.

The use of human wastes for compost, or in raw form, to fertilize fields--and even fishponds--is common throughout rural Asia, and cultural acceptance of this practice has, in part, led to the problems of urban human waste. The necessity for maintaining organic matter in agricultural soils, especially those in the humid tropics, suggests that to the extent possible the fertilizer value of human and other organic wastes be exploited. Urban human wastes, therefore, can be viewed as a valuable resource, especially in heavily populated regions with low man/arable-land ratios. In Asia, however, chemical fertilizers are becoming cheaper than organic fertilizers and are undermining the economics of composting city wastes. Also, transport and handling costs are higher for organic fertilizers than for chemical fertilizers. The proximity of farming zones to a city and the transport economics are, of course, important variables.

The economic relationship between chemical fertilizer and fertilizer from the composting of human and other organic wastes generated in cities is not necessarily static. The increasing scarcity of petroleum and natural gas relative to demand indicates that costs of these products will rise. Eventually, priority in their use may be placed on fuel and products such as plastics. Natural gas is the source of nitrogen in chemical fertilizers, and if priority is assigned to its use as fuel, the cost of nitrogenous fertilizer will increase, as has occurred recently. The economics of composting urban human wastes, and other organic wastes, should be assessed in the light of these trends. *If sanitary criteria could be met, and water quality safeguarded, the use of a portion of urban organic wastes in the form of compost could become economically attractive. Designers of waste-collection systems in growing cities should consider how this possibility could be realized.*

An alternative to fermentation or composting of human wastes is combustion. The wet-oxidation combustion (Zimmerman) process is being used on a limited basis in Seoul and Tokyo. Seoul eventually plans to burn most of the city's human wastes in this way until a water-carriage system has been constructed. The wet-oxidation method involves pumping air into waste followed by combustion under high temperature and pressure conditions. This results in oxidation of a portion of the night soil and sterilization so that there can be no public health problems associated with subsequent disposal. The technology of wet-oxidation combustion is highly sophisticated and requires skilled operators for controlling and maintaining the process. The sludge created by the process is difficult to de-water, has practically no nitrogen, and is of no commercial value as a soil conditioner.

For an already sizable city, the economic advantages of the wet-oxidation step derive in part from the high costs of conversion from the cesspool system directly to the water-carriage technology. It has been estimated that in Tokyo the cost of a complete waterborne system, including the installation of flush toilets, sewers, and sewage-treatment plants, would be 20 times that of a system based on cesspools with periodic night-soil collection and wet-oxidation combustion treatment (Thomas, 1972). Both capital investment and yearly operating and maintenance costs of the two systems were compared.

In wet-oxidation the treatment capacity can be built up incrementally and, if necessary, plants can be moved from one city to another. A plant can be installed and put into operation within one to two years. The plants are conservative of water. They are not complicated by seasonality of rainfall and flash flooding as are water-carriage systems that do not separate storm and domestic wastewaters. In Asia, the system is compatible with the culturally accepted privy. Should the economics of night-soil-derived organic fertilizer and chemical fertilizer become

Plate 3. Compost heaps, rural Korea. Compost from human wastes, crop residues, weeds, and other organic matter helps maintain soil productivity. Sanitary composting of urban organic wastes may become economical with the rising price of chemical fertilizers.

reversed, such a system would have the advantage that a switch to composting could be accomplished more easily that in the case of treatment plants, since collection would be specific to human wastes. In the United States, use of treatment-plant sludge for fertilizer has been found to be complicated by the presence of such substances as toxic metals which can pollute the soil and harm plants.

Disadvantages of the wet-oxidation combustion system lie in requirements for highly skilled technicians for system maintenance, relatively high initial capital costs, and relatively low utility of the approximately 2 percent residue of the combustion process. Many sanitary engineers consider the system too complicated and susceptible to malfunction. And, as mentioned previously, human wastes comprise only a portion of the total organic wastes which may enter water systems. Additional wastewater collection and treatment would be needed. *Thus, in balance, the wet-oxidation system and other combustion systems (such as pyrolysis) would appear to be interesting alternatives only for already large cities (such as Seoul) which seek interim solutions to the sanitary disposal of human wastes until such time as sanitary collector-sewers have been constructed and sewer lines provided to residences.*

Options for the control and treatment of industrial wastewaters are not discussed due to the great differences in the nature and amount of pollution within this category of pollutants. Up-to-date knowledge on industrial wastes and their treatment can be found in the yearly reviews of literature of the *Journal of the Water Pollution Control Federation* (U.S.A.), published in June each year (Water Pollution Control Federation, 3900 Wisconsin Avenue, N.W., Washington, D.C. 20016, U.S.A.). Key works concerning industrial wastes and effluents are listed in the World Bank Publication *Environmental, Health, and Human Ecologic Considerations in Economic Development Projects* (World Bank, 1973).

c) *Air Policy*

Much less is known of the public health impacts of air pollution than of the public health impacts of water pollution. Although air pollution in urban areas is reversible, the probable long-term cardiovascular and pulmonary impacts of air pollution appear irreversible and difficult to treat when full blown (Nadler et al., 1970). These include bronchitis, bronchial asthma, emphysema, and lung cancer, all of which may be caused primarily by cigarette smoking but which have been found to be aggravated by air pollution.

Although the health impacts of air pollutants such as carbon monoxide and sulfur dioxide can be separated experimentally, the lung is exposed to all air pollutants. The combined (or synergistic) effects of a number of pollutants can be more serious than the sum of their individual effects

(HEW, 1969). *Climate, local weather, season, and population density are critical variables influencing the seriousness of air pollution episodes. Duration of exposure and the age and health of the individual are important determinants of the physiological effects of air pollution, and they spell the difference between temporary or permanent bronchial irritation or even death.*

The most pervasive urban air pollutants are those derived from the combustion of coal, gasoline, and fuel oils: carbon monoxide, carbon dioxide, sulfur oxides, nitrogen oxides, hydrocarbons, and suspended particulate matter. Photochemical smog also may be generated by the action of ultraviolet rays on nitrogen oxides. Smog consists of ozone and peroxyacyl nitrate (PAN). PAN irritates the eyes and damages mucous membranes.

It would seem on the surface that air pollution problems do not become serious until industrialization reaches fairly advanced stages with the presence of large numbers of automobiles and other vehicles with internal combustion engines. However, this is not necessarily true in Third World cities, as indicated by the Seoul case study. In fact, *the typically high congestion in the central business districts of developing-country cities results in ambient air pollution and levels of human exposure comparable to those of large cities in North America and Europe.*

Information on air pollution and impacts can be found in a number of sources. Stern's three-volume *Air Pollution* (Stern, 1968) is the most authoritative single source. The National Air Pollution Control Administration, now within the U.S. Environmental Protection Agency, has published an air quality criteria series with individual monographs on particulate matter (HEW, 1969), sulfur oxides, carbon monoxide, photochemical oxidants, and hydrocarbons (HEW, 1970), and nitrogen oxides (EPA, 1971). In a companion monograph series, control techniques are reviewed for CO, NO_x, and hydrocarbons from mobile sources (HEW, 1970); and for particulates (EPA, 1969) and sulfur oxide air pollutants (HEW, 1969). In addition, control techniques for certain industrial air pollutants--asbestos, beryllium, and mercury--have been reviewed. The Committee for Challenges to Modern Society has published documents on air quality monitoring, assessment guidelines, and criteria for particulates, sulfur oxides, and carbon monoxide (NATO/CCMS, 1971 and 1972). By the end of 1973, it was to have published criteria for nitrogen oxides, hydrocarbons, and photochemical oxidants.

i. *Air pollution policy*

Public health should be the principal criterion for formulating air pollution policy. In 1972 WHO reviewed urban air pollutants in relation to public health and developed criteria and guides on which to base air-quality standards. These are published in *Health Hazards of the Human Environment* (WHO, 1972), and pertinent data is summarized below. Protection of susceptible economic plants

and materials also may become important policy considerations. Air pollution may seriously damage irreplaceable historical monuments or statuary. Gardens and orchards that are adjacent to or within a city and contribute to the food supply and economy may be damaged by air pollutants.

A policy can focus on the control of emissions from mobile and stationary sources but it will not necessarily be effective if the movement and concentration of pollutants in the atmosphere are not taken into account and related to factors affecting human exposure and probability of serious air pollution episodes. An adequate policy must therefore emphasize ambient air quality and anticipate the likelihood of episodes, especially as affected by climatic factors and the seasonality of fuel combustion. Consequently, in addition to emissions data, good meteorological and microclimatic data are required. A growing city should install the meteorological stations needed to understand and predict such phenomena as wind movement, temperature inversions, and insolation in addition to standard climatic variables such as rainfall, humidity, and temperature.

Ambient standards should be set at various levels of concentration and duration for carbon monoxide and sulfur, two of the more serious pollutants in terms of public health. The expected adverse effects of sulfur dioxide and smoke and of photochemical oxidants appear in Tables 4 and 5. Health impacts of various ambient concentrations of carbon monoxide are summarized in Table 6. Exposure to carbon monoxide concentrations of 80 ppm or more can occur in underground garages, tunnels, and loading platforms and inside motor vehicles on city streets in heavy traffic. Concentrations of carbon monoxide in heavily congested business districts can be as much as five times higher than in residential areas.

Because young people and hospitalized persons--especially those with pulmonary disease and cardiac disorders--are particularly sensitive to air pollution, appropriate standards should be set and enforced for air quality around schools, nurseries, and hospitals. Locating hospitals and schools at sites least likely to receive heavy air pollution is one obvious method to help ensure the necessary levels of air quality. This is an additional reason to collect meteorological data needed to predict movements and concentrations of air pollutants.

A policy on air pollution may assume the inevitability of pollutant-loading of a city's atmosphere. In order to minimize the associated impacts, such a policy must be grounded upon calculations of local as well as total pollution-loading. For instance, along major transportation corridors traversed by vehicles with internal combustion engines, high local concentrations of air pollutants are generated. This fact points up the essential relationship between air pollution policy, transportation policy, and, ultimately, energy and fuels policies. It naturally raises the question of the economics of energy as influenced by national and international trends in supply and demand.

Table 4 Expected Adverse Effects of Sulfur Dioxide and Smoke

Concentration[a] (μg/m³)		
Sulfur dioxide	Smoke	Adverse effect
500 (daily average)	500 (daily average)	Excess mortality and hospital admissions
500 250[b] (daily average)	250 (daily average)	Deterioration of patients with pulmonary disease
100 (annual arithmetic mean)	100 (annual arithmetic mean)	Respiratory symptoms
80 (annual geometric mean)	80 (annual geometric mean)[c]	Visibility and or human annoyance effects

[a]Measured by the method recommended by the British Standards Institution (1963), whereby both pollutants are measured at the same time. These values may have to be adjusted when other procedures are used.

[b]Based on high-volume samplers.

Source: WHO, 1972, p. 38.

Table 5 Health Effects of Photochemical Oxidants

Health effect	*Level and duration of exposure*
Increased mortality	Not reported to date
Increased asthmatic attacks	250 μg/m³ for 1 hour[a]
Pulmonary dysfunction	200 μg/m³ for 1 hour
Annoyance and eye irritation	200 μg/m³ for 1 hour

[a]Oxidants usually peak around midday, when incoming shortwave solar radiation is greater. In Los Angeles, where the highest concentrations of oxidants in the U.S.A. have been found, the monthly mean of maximum daily one-hour average concentrations has been measured at 333 micrograms per cubic meter, or 0.17 ppm (HEW, 1970, Air quality criteria for photochemical oxidants).

[b]Oxidant as measured by the neutral-buffered KI method and expressed as ozone.

Source: WHO, 1972, p. 40.

Table 6 Health Effects of Carbon Monoxide

Concentration of CO in Air	Percent of Carbomonoxy-hemoglobin in Blood	Symptoms
Up to 300-400 ppm	30-40% and above	Severe headache, dim vision, nausea, collapse.
100 ppm	Up to 20%, depending on exposure and activity of subject	Headache at 20%. Impaired performance on simple psychological tests and arithmetic above 10% CO in blood.
	20% in dogs exposed for only 5.75 hours per day for 11 weeks	Brain and heart damage found at autopsy.
50 ppm and below	2-4% and above, maximum of about 8%	Ability to detect a flashing light against dim background worsens with increasing amounts of CO. Lowest point shown was 4% but authors state that even the CO from a single cigarette could be shown to cause rise in visual threshold. It is obvious, therefore, that smoking and exposure to CO from auto exhaust interact. Subjects presented with two tones and asked to judge which is longer. Judgment impaired at this level of CO in the air; lower levels of CO not studied. Results interpreted as impairment of ability to judge time. Not known whether this may influence person's ability to drive safely. Another author concluded that 1-2% CO in the blood should cause a detectable number of errors on psychological tests if a sufficiently large-scale experiment were done.
15 ppm	Up to 2.4%	New York's air quality goal. Even this amount of CO could cause some of the effects on vision and loss of judgment of time that are mentioned above.

Source: Nadler et al., 1970, p. 12.

It is clear that these trends will be basic determinants and constraints on a policy for controlling air pollution--perhaps more so than in the case of the supply and demand projections for water resources on water pollution control policy. Consequently, guidelines statements on policies for air pollution control are subject to considerable qualification because of the conjectural nature of energy supply projections, particularly of petroleum and gas, and the considerable differences in energy resource endowments among nations.

Notwithstanding these influences on air pollution policy, minimum ambient quality goals should be set at some stage in a city's growth, either by the city, or, as is more likely, by central government. WHO has considered that a long-term goal should be to keep exposure to certain air pollutants as low as possible, taking into account the limits to present knowledge of the long-term health effects of low concentrations of a number of pollutants. The goals recommended are shown in Table 7.

Table 7 Recommended Long-Term Goals for Air Pollutant Levels

Pollutant	Limit
Sulfur oxides [a]	Annual mean 60 μg/m³ 98 % of observations below 200 μg/m³
Suspended particulates [a]	Annual mean 40 μg/m³ 98 % of observations below 120 μg/m³
Carbon monoxide (non-dispersive infra red)	8 hour average 10 mg/m³ 1 hour maximum 40 mg/m³
Photochemical oxidants as measured by neutral buffered KI method and expressed as ozone	8-hour average 60 μg/m³ 1-hour maximum 120 μg/m³

[a]Measured by the method recommended by the British Standards Institution, whereby sulfur oxides and suspended particulates are measured in conjunction. Where other methods are used, an appropriate adjustment may be necessary.

Source: WHO, 1972, p. 41.

ii. *Industrial air pollution*

Since industry is not necessarily limited to large urban areas or to locations with dense populations, emissions standards should be the object of a national industrial pollution control policy that would enable cities to adopt stringent standards as required by local conditions. Policies must consider the internal working environment as well as the general environment outside the industrial plant.

The control of industrial emissions of air pollutants should be based on a policy whose objectives are to safeguard the health of industrial workers and the residents in the immediate environs as well as to prevent damage to vegetation and materials in the environs. Environs should include zones outside of city boundaries, given the

possibility that industry may be located on the peripheries of a municipality. Maximum concentrations of various toxic or damaging air pollutants should be set for the interior of industrial buildings and for the air at some specified distance from the plant boundary.

A joint ILO/WHO Committee recommended safe concentration zones for the industrial working environment for 24 substances, for which there existed relative agreement between standards set by the U.S.S.R. and the American Conference of Governmental Industrial Hygienists. The standards recommended for international adoption are shown in Table 8.

Table 8 Recommended Air Quality Standards for Industrial Working Environments

Substance	Safe concentration zone (mg/m^3)
Hydrogen chloride (hydrochloric acid)	5-7
Phosgene	0.4-0.5
Hydrogen sulfide	10-15
Sulfur dioxide	10-13
Sulfuric acid and sulfuric anhydride	1
Ozone	0.1-0.2
Ammonia	20-35
Arsine	0.2-0.3
Ethanol	1000-2000
Methyl acrylate	20-35
Nitrobenzene	3-5
Dinitrobenzene	1
Dinitrotoluene	1-1.5
Trinitrotoluene	1-1.5
Parathion	0.05-0.1
Iodine	1
Beryllium and compounds (as Be)	0.001-0.002
Molybdenum, soluble compounds, dust (as Mo)	4-5
Vanadium (as V_2O_5)	
dust	0.5
fume	0.1
Ferrovanadium	1
Zinc oxides (fumes)	5
Zirconium and compounds (as Zr)	5
Chlorinated derivatives of diphenyl	1
Chlorinated derivates of diphenyloxide	0.5

Note: The figures given are used by some authorities as maximum values and by others as time-weighted average values.

Source: WHO, 1972, p. 135.

Policy should anticipate the possible need for more stringent emissions standards under certain circumstances in order to take into account climatic influences and the possible proximity of sensitive species of economic plants, such as certain vegetables and orchard plants. Industrial air pollution policy should influence industrial location so as to avoid siting that results in unusual concentrations or high-potential impacts. This can be accomplished by requiring environmental impact assessments of proposed industries, or through land-use planning and zoning, which, among other objectives, attempt to minimize air pollution impacts. Stack-emissions standards should be explicit in policies and laws affecting industries; however, standards are not suggested here. The reader can refer to Stern (1968) or the World Bank's publication *Environmental, Health and Human Ecologic Considerations in Economic Development Projects* (World Bank, 1973). The latter includes a section on standards as well as on guidelines for assessing the environmental impact of various types of industries.

d) *Solid Waste Policy*

Of the various environmental problems experienced by rapidly growing cities in developing countries, solid waste is perhaps the least serious one. Abundant, cheap labor and scarce resources in most urban areas of developing countries operate to prevent a solid-waste problem. In essence there is little that is wasted, since poorer or unemployed people find it profitable to salvage and use, or sell, materials that have been discarded. In Seoul, the salvage and collection of discarded or "waste" materials such as rags, cans, scrap metal, wood, bottles, and paper are very efficient. It was judged that there was little that could be done to improve on solid-waste management. Only anthracite briquet ashes in Seoul have required explicit municipal attention. The large amounts generated and the scarcity of suitable disposal sites have combined to create a problem needing municipal action.

Solid-waste management likely will not require a concerted policy and plan in rapidly growing cities as long as cheap labor is available and resources are scarce relative to purchasing power of the lowest income levels. This proposition, of course, is not an implicit endorsement of the underdeveloped conditions that bring about this situation. Rather, it recognizes a reality which explains why the solid-waste problem is not a serious one in developing-country cities. If, however, fuel, construction materials, and other goods are provided at prices which undermine the economics of solid-waste salvaging, or if income and employment improve to an extent that produces similar results, then a solid-waste management problem is predictable. General and universal trends towards resource scarcity do, however, suggest that in all countries, both developed and developing, recycling of used materials will become increasingly profitable. It is not likely that developing-country cities will reach the generation levels of solid waste that have been experienced in North American cities.

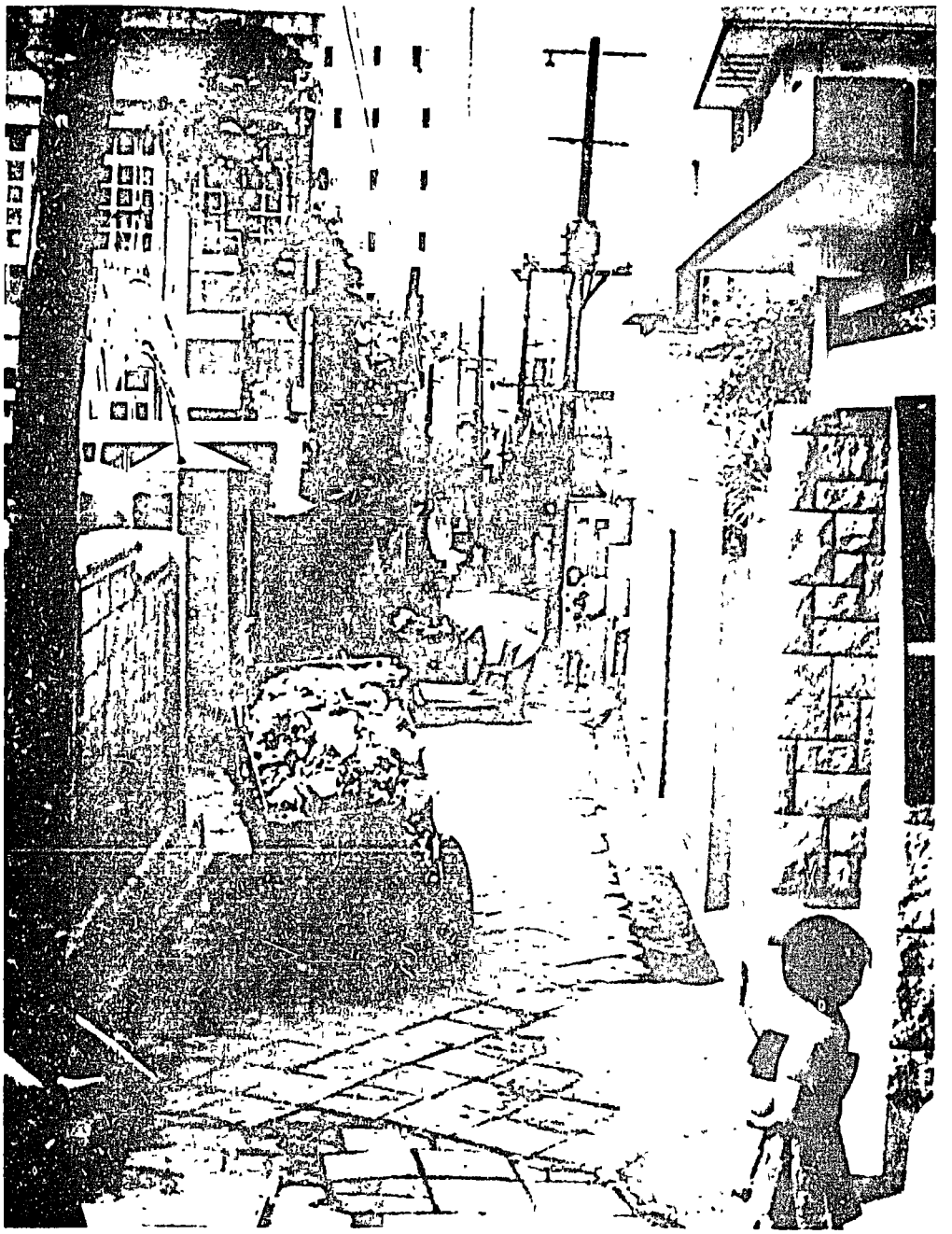


Plate 4. Trash collectors, Seoul. Narrow streets prevent the entry of trucks. Efficient collection reflects the value of wastes in a situation of scarcity and low labor costs.

The transportation aspects of solid-waste collection in cities are liable, however, to require special attention. Carts pushed by hand or powered by bicycles and animals are the usual conveyances employed by junk and trash collectors. They enable access to the narrowest streets and alleys but can create traffic-flow problems, especially in congested city centers. Solutions to traffic-flow problems should accomodate the smaller conveyances as long as they are needed for waste collection. Aspects of transportation and central business district congestion are discussed further in the following section.

2. *Environmental Policy in the Context of Major Issues*

A number of important issues affecting urban environmental quality became apparent in the Seoul case study. These issues are central business district congestion, transportation, squatters, and slums. They are generally recognized as priority issues in urbanization. Environmental policy on open space, air pollution, and water pollution obviously will be influenced by these issues. They are briefly discussed here in terms of their implications for environmental policy.

a) *Central Business District Congestion*

Central business district (CBD) congestion is a phenomenon relatively independent of the total number of automobiles in a city. Rather it is determined, as Seoul's case shows, by the trip-making rate of existing automobiles and other vehicles, the width of streets and pedestrian walkways (and other factors which constrain vehicular flow), and the degree to which jobs and commercial transactions are concentrated in the CBD. The relatively greater importance of face-to-face communication in business transactions in developing economies--as opposed to telephonic and written communications--is an additional factor that increases CBD trip-making and pedestrian movement. Cities of greater antiquity, that were small but now are beginning to grow, are further plagued by narrow streets and by street patterns that were not designed for automobile and bus traffic.

Besides causing inefficiency at the nerve point of a city, CBD congestion results in locally serious air and noise pollution and potentially high rates of traffic accidents. The goal of preventing congestion in the CBD is clearly compatible with that of limiting air pollution and other environmental impacts.

Mass transit is clearly the best solution to CBD traffic congestion. Also, timely decentralization of CBD functions should be anticipated. This proposition is, of course, closely allied to transportation planning.

Heating plants in CBD office buildings contribute heavily to CBD air pollution in some developing-country primate cities. This pollution may be aggravated by

temperature inversions and may combine with photochemical smog to produce seasonal pollution episodes. Emission controls and use of fuels having low sulfur content can be considered. In addition, building-code policy should consider the advantages of energy-conservative architecture and construction, such as the more efficient use of insulation, solar heat, and natural air movements. Finally, incineration of wastes in office and apartment buildings contributes to air pollution. It can best be solved by collection and incineration in a single municipal facility equipped with modern emission-control technology.

Since the central business district is likely to develop in what historically has been the center of a city, policy to avert congestion faces difficult constraints, such as the existence of very narrow streets, historical buildings, parks, and sites whose preservation is desirable. *For policy makers and planners addressing the future of a city that is likely to grow several times in size, and whose functions will concentrate at least initially in a central district, the advantages and disadvantages of preserving historical sections must be carefully weighed.* Historical heritages eventually will take on great value as national and international tourist attractions. These can include ancient quarters with narrow streets and particularly representative forms of architecture. If engulfed by a modern business district these attractions could become obstacles to efficiency. Thus, long-range plans should consider the option of extending and/or locating the modern central business district so as to avoid conflicts with ultimately valuable historical features of the old central city.

The various physical and psychological impacts of congestion on pedestrians can be buffered and kept to a minimum by physical separation of pedestrian and vehicular traffic. However, effective early planning for this must be based upon policy affecting growth limits of the CBD, e.g., building heights (therefore, floor space) and kinds of governmental, commercial, and financial activities expected or planned for the future CBD. *An optimal policy for preventing excessive congestion would determine an upper level of pedestrian and vehicular traffic as a guideline for planning, zoning, and building codes.* The policy could then be translated into goals and planning guidelines for the provision of public open space, pedestrian walkways, and other facilities designed to ameliorate the human impacts of CBD congestion. In addition to criteria for preventing congestion to the extent possible, aesthetic criteria can and should be employed. Targets for open space must be set at an early stage to avoid the virtually insurmountable obstacles of building momentum and escalating real estate values which will foreclose many alternatives to provide for open space and special pedestrian facilities.

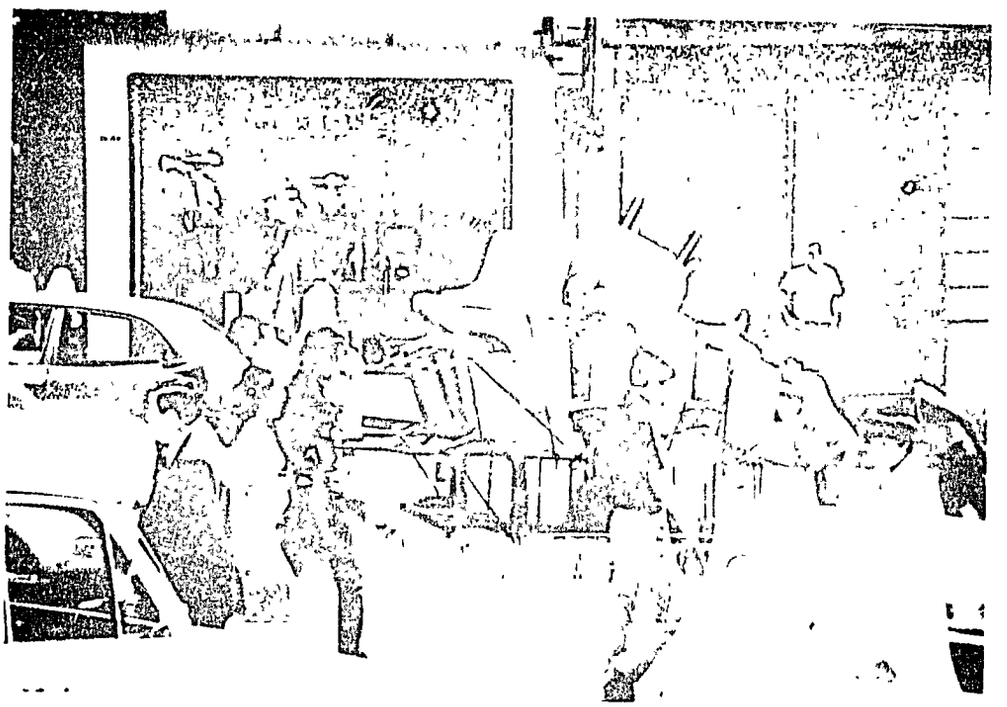


Plate 5. Congested street, central Seoul. Cars, hand-powered vehicles, and pedestrians intermingle to create traffic conditions unique to the narrow streets characteristic of the central district in most cities of the developing countries.

b) *Transportation*

As mentioned previously, the implications of the world energy situation cannot be discerned with the accuracy required to formulate guidelines that are affected by energy. Transportation is clearly influenced by this circumstance. However, an energy shortage relative to demand as determined by present consumption trends is a certainty. Many students of the problem believe that the highly polluting private automobile powered by the internal combustion engine is destined to become obsolete. There is also a general agreement that mass transportation is the best alternative for moving large numbers of people.

The World Bank has considered the high costs of providing the necessary infrastructure for expansion of private vehicle fleets in developing-country cities. It concluded that, for economic as well as environmental reasons, more reliance must be placed on mass transit, especially fleets of buses (World Bank, 1972). The two principal mass transit technologies--buses and rapid rail transit systems--differ in their environmental impacts, but economic differences are undoubtedly of more critical importance. Diesel rather than gasoline engines may be better for buses. Compared to gasoline engines, diesel engines emit lower amounts of carbon monoxide and hydrocarbons but greater amounts of nitrogen and sulfur oxides (EPA, 1973). Also, if overloaded or poorly adjusted, diesel engines may emit large amounts of black smoke (particulates). A well-tuned diesel engine will not emit visible smoke, however. The Seoul case study underlined the importance of poorly maintained and overloaded engines--especially in diesel buses--as a factor contributing significantly to air pollution. *Periodic, effective control and inspection of conveyances with internal combustion engines should be a major goal of urban transportation policy aimed at limiting air pollution.*

Transportation affects the type, intensity, and spatial disposition of urban land uses more than any other type of urban infrastructure. In addition to being costly and generating large benefits, transportation infrastructure sets virtually irreversible patterns of land uses and movement of people and goods. Above all, its influence on the economics of urban land uses can have overwhelming influence on low-intensity, "nonproductive" (in an economic sense) land uses such as parks, schools, and metropolitan gardens. In the absence of intervention via public agencies, the routing of major transportation corridors can destroy the possibility of maintaining or obtaining lands for low-intensity use. *It is clear that transportation planning must include land-use planning, especially in relation to public land uses, and that planning be based upon environmental and other policies that view the long term.*

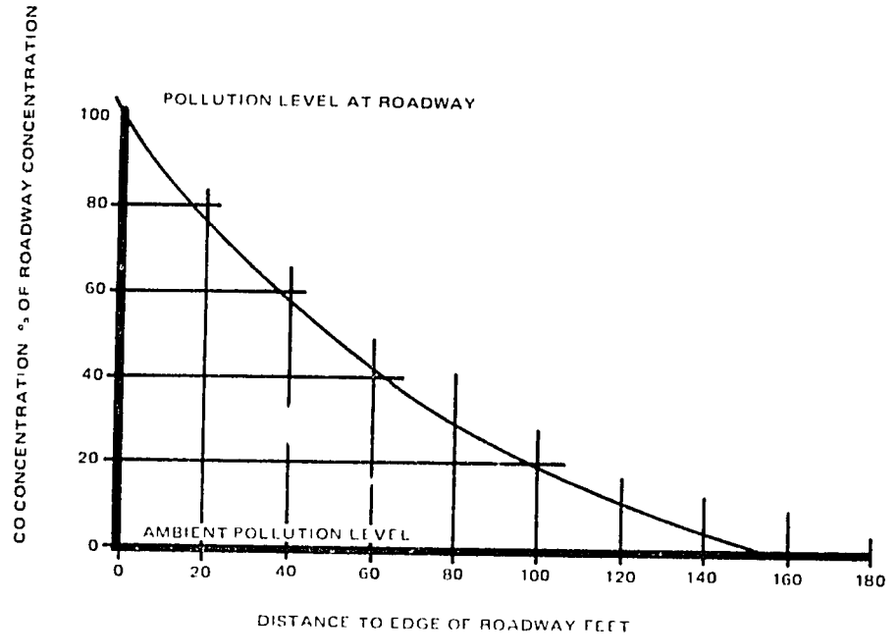
Because transportation affects numerous aspects of a city's environment, only through comprehensive planning can adverse environmental impacts be anticipated and averted

to the extent possible. A study undertaken for the U.S. Environmental Protection Agency on the role of urban planning in reducing air pollution (Vorhees, 1971) arrived at a number of conclusions that are relevant to rapidly growing Third World cities, although the context of this research was U.S. cities. Urban planning agencies can help reduce air pollution by evaluating, proposing, and implementing measures which help disperse pollutant concentrations, reduce exposure of people to pollutants, and improve efficiency of urban travel. It was concluded that, in the short term, the urban planner can obtain the greatest impact by traffic-flow improvements, improvement of highway land-use relationships, tighter control over location of stationary air pollution sources and the land uses around such sources, and creation of traffic-free zones within congested activity areas.

Certain kinds of facilities such as playgrounds, schools, and hospitals should be located so as to avoid heavy air pollution from high-volume transportation corridors carrying internal-combustion-powered vehicles. The siting of these facilities should be sufficiently removed from major corridors to avoid the impacts of local air pollution. Figure 3, showing the reduction in carbon monoxide pollution influenced by distance from the roadside, indicates that concentrations of carbon monoxide are halved at less than 50 feet of distance. *Tree plantings an increase the buffering function of space to both air pollutants* (Table 9) *and noise.* Certain species of trees have been particularly suitable for urban planting (Table 10) in temperate climates. Species should be selected according to the conditions of the site and the functions desired. In the tropics and subtropics, research and observations for the selection of suitable species is needed.

The heavy reliance in most developing-country cities on human-powered conveyances (such as bicycles, heavy-duty tricycles, and hand-drawn carts and wagons) as well as on animal-drawn conveyances should be translated into transportation planning criteria. Appropriate roadways and traffic patterns must be planned. The alternative of banning these vehicles has the disadvantage of creating total dependence on larger, internal-combustion-powered vehicles. Oil shortages in the United States and Europe have dramatized the utility of the bicycle as a feasible mode of urban transportation, and many cities in these countries are now constructing or planning to construct special bicycle lanes. Developing-country cities in the process of planning their transportation networks should seriously consider the implications of oil shortages to the economics of indivdual modes of conveyance. *The provision of special roadways, separated from automobile, bus, and truck traffic, should be considered for the accomodation of bicycle and other alternative, slower modes of conveyance.*

Figure 3 Pollution Level Versus Distance to Edge of Roadway



Source: Vorhees and Associates, 1971, pp. 2-35.

Table 9 Reduction of Selected Gaseous Pollutants by Forest Vegetation

	Concentrations of Pollutant (mg/m^3)			
Pollutant	1000 m from Source	1500 m from Source, no Green Zone	1500 m from Source, with 500 m Green Zone	Percent Reduction Attributed to Green Area
Sulfur dioxide	0.27	0.14	0.08	22
Hydrogen sulfide	0.07	0.03	0.025	7
Nitrogen oxides	0.22	0.13	0.07	27

Source: Detwyler and Marcus, 1972, p. 87.

Table 10 Trees with Special Characteristics for Urban Planting (after American Society of Planning Officials, 1968)

Characteristics	*Kinds of Trees*
Favorable:	
Resistant to extreme city conditions	Tree of heaven, box-elder, white mulberry (all grow where nothing else will, but are not generally desirable)
Resistant to most city conditions	Norway maple, horse chestnut, green ash, hawthorn, ginkgo, London plane, honey locust, red oak, linden, European hornbeam
Fast growth	Red maple, white ash, ginkgo, green ash, honey locust, European larch, cucumber tree, pin oak, black locust, mountain ash, American linden, Chinese elm, pitch pine, red pine, white pine, Scots pine
Privacy and protection	Evergreens or mixtures of evergreens and deciduous trees, euonymus, firethorn, lilacs, mock orange
Resistant to air pollution	Birch, catalpa, elms, ginkgo, hawthorn, London plane, magnolia, tree of heaven, English oak, tulip tree
Resistant to most biotic diseases and insects	Russian olive, ginkgo, honey locust, Kentucky coffee tree, golden rain, sweet gum, cucumber, sweet bay, magnolia, sour gum, sourwood, and cork
Resistant to ice damage	Beech, catalpa, ginkgo, golden rain, hawthorn, hop hornbeam, horse chestnut, locust, oaks, yellow birch
Flowers and color	Dogwood, English hawthorn, honey locust, golden rain, tulip, cucumber, sweet bay, magnolia, beach plum, Japanese cherry, black locust, fringe-tree, flowering fruit trees

Sweet scents	Silver wattle (Acacia), amur maple, silk tree, English hawthorn, laurel or sweet bay, sorrel or sourwood, magnolias, citruses, pines, and balsams
Edible fruits that attract birds	Cotoneasters, flowering crabapple, sapphire berry, spreading juniper, hawthorn, sumacs, hollies
Detrimental:	
Weak-wooded (break in storms)	Chinese elm, silver maple, mountain ash
Prone to drip on cars	Birches, elms, lindens
Prone to clog drains and sewers	Willow, poplar, silver maple, catalpa, elms, some locusts, lindens, black walnut, horse chestnut

Source: *Urbanization and Environment: The Physical Geography of the City* by Thomas R. Detwyler and Melvin G. Marcus. © 1972 by Wadsworth Publishing Company, Inc., Belmont, California 94002. Reprinted by permission of the publisher, Duxbury Press.

c) *Squatters and slums*

While squatter settlements initially will be slums because of overcrowding, poor housing quality, lack of services, and general poverty, it was noted that in Seoul some squatters made efforts to improve their dwellings. That is, squatter settlements may improve and need not remain slums. Slums are not necessarily the result of illegal settlement although they tend to be equated with squatters. Both, however, are symptomatic of the urban housing scarcity in most large cities in the Third World; and as yet no nation has had the ability to correct this scarcity completely. *Squatter settlements and slums have been the only housing possibility for low-income urban dwellers,* many of whom are part of the flood of in-migrants that have caused the rapid growth of Third World cities (Tables 11 and 12).

Various approaches to the urban housing scarcity and the squatter and slum problems have been tried. As mentioned in the case study summary (Part III), Seoul attempted a relocation of squatters into an outlying satellite city as well as in low-cost, "citizens" apartments in the city. Also, additional squatting was controlled by means of strict prohibition and continuous surveillance. The existence of very efficient municipal administration, with heavy penalties and aerial surveillance at the neighborhood level, has made enforcement of prohibitions in Seoul uniquely effective

Table 11. Estimates of Migrants as a Percentage of Recent Population Increases

City	Period	Total Population Increase (Thousands)	Migrants as a Percentage of Total Population Increase
Abidjan	1955-63	129	76
Bogota	1956-66	930	33
Bombay	1951-61	1,207	52
Caracas	1950-60	587	54
	1960-66	501	50
Djakarta	1961-68	1,528	59
Istanbul	1950-60	672	68
	1960-65	428	65
Lagos	1952-62	393	75
Nairobi	1961-69	162	50
Sao Paulo	1950-60	2,163	72
	1960-67	2,543	68
Seoul	1955-65	1,697	63
Taipei	1950-60	396	40
	1960-67	326	43

Source: World Bank, 1972, p. 80.

Table 12 Extent of Slums and Uncontrolled Settlements in Various Cities in Developing Countries

Country	City	Year	City Population (Thousands)	Uncontrolled Settlement: Total (Thousands)	Uncontrolled Settlement: At Percentage of City Population
Africa					
Senegal	Dakar	1969	500	150	30
Tanzania	Dar es Salaam	1967	273	98	36
Zambia	Lusaka	1967	194	53	27
Asia					
China (Taiwan)	Taipei	1966	1,300	325	25
India	Calcutta	1961	6,700	2,220	33
Indonesia	Djakarta	1961	2,906	725	25
Iraq	Baghdad	1965	1,745	500	29
Malaysia	Kuala Lumpur	1961	400	100	25
Pakistan	Karachi	1964	2,280	752	33
Republic of Korea	Seoul	1970	440 (d u)	137 (d u.)	30
Singapore	Singapore	1966	1,870	980	15
Europe					
Turkey	Total Urban Population	1965	10,800	2,365	22
	Ankara	1965	979	460	47
		1970	1,250	750	60
	Izmir	1970	640	416	65
North and South America					
Brazil	Rio de Janeiro	1947	2,050	400	20
		1957	2,940	650	22
		1961	3,326	900	27
	Brasilia	1962	148	60	41
Chile	Santiago	1964	2,184	546	25
Colombia	Cali	1964	813	243	30
	Buenaventura	1964	111	88	80
Mexico	Mexico City	1952	2,372	330	14
		1966	3,287	1,500	46
Peru	Lima	1957	1,261	114	9
		1961	1,716	360	21
		1969	2,800	1,000	36
Venezuela	Caracas	1961	1,330	280	21
		1964	1,590	556	35
	Maracaibo	1966	559	280	50

Note: d.u.=dwelling units

Source: World Bank, p. 82.

in comparison to other developing-country cities. Relocation was judged a qualified success and of only short-term value. Economic disincentives were considered important after 1971 in stemming the tide of in-migrants and easing pressures for new squatter construction. In essence, however, these solutions have focused on the social problems represented by squatters and slums.

The rehabilitation or improvement approach adopted in some cities is premised upon the potential opportunity for utilizing for productive purposes the improving economic status of the slum dweller. The sites and services approach* also attempts to tap the incentive for a low-income person to invest whatever savings he has in house construction and/or improvement. The World Bank views this approach as particularly attractive (World Bank, 1972). It differs from resettlement or rehabilitation in that it is not reactive. A city that is in the early stages of growth and that will predictably attract low-income in-migrants during growth should carefully consider what policies and investment it should carry out if it wishes to avoid the seemingly intractable problems of squatting and slums. *A realistic policy approach would assume the inevitability of a certain amount of uncontrolled construction and the consequent service and assistance needs, as well as the requirements for controlled settlement for low-income in-migrants.*

Water pollution is the most important over-all environmental consequence of uncontrolled settlement. Basic water supply and wastewater collection infrastructure will be inadequate or may quickly become so with overcrowding. Early policy decisions should be made concerning the water supply and wastewater infrastructure and waste-disposal services that are to be provided in low-income housing areas. Improvements in water supply should be accompanied by provision for wastewater collection and treatment. If scarcity of resources results in a policy emphasizing water supply and distribution, and later attention to wastewaters, then the impact of untreated wastewaters on receiving waters should be carefully gauged and, to the extent possible, internalized as a cost. If a limited or no-treatment policy is deemed feasible or desirable, even after internalizing water pollution impacts, it may turn out that some areas in a city would cause fewer or lesser impacts than others.

The inevitability of the need for a wastewater collection and treatment system should be anticipated. In general, when consumption reaches the rate of 75 liters per person

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*The sites and services approach usually involves some combination of a legally acquired and demarcated site and varying amounts of water, drainage, sewage, electrical, and street or road services. Core housing is sometimes included.

per day (e.g., typical of conveniently located public fountains or standpipes), wastewater volume will reach a level that requires special drainage and conveyance. Density of population, degree of health hazard (such as potential contamination of shallow wells), and physical features affecting drainage will be important additional considerations in the design and timing of wastewater collection and treatment measures.

A policy which deliberately postpones investment in sewers and sewage treatment should be followed only after considering the advantages of various sites for low-cost housing. It follows that a city should be prepared to influence the location of low-income settlements, and, to do so, areas best suited for such settlements should be set aside before settlement has become uncontrollable. This would also further the goal of preserving open space set aside by a city in its early stages of growth. It is clear, however, that if the savings potential of low-income settlers is to be channeled into private improvement of housing, employment opportunities, low-cost transportation, and basic community services making for a healthy environment must be provided. The initial difficulties experienced in Seoul's satellite city demonstrate how critical these ingredients are for the development of a viable community.

To the extent that the cost of infrastructure and services to urban dwellers decreases with density of population, high concentrations of people in low-income housing areas can be economically advantageous. However, the public health consequences of crowded conditions demand special attention, particularly if rural in-migrants suffer from higher rates of communicable diseases such as tuberculosis. *Medical services should be tailored to the communicable disease and other public health problems of low-income housing dwellers.* For example, in-migrants from regions with high incidence of communicable disease should be monitored and given appropriate medical attention.

Diseases transmitted by arthropod vectors such as malaria and Japanese encephalitis may require special attention. Their mosquito vectors may increase in urban fringes where abandonment of rice paddies or blocked drainage may create bodies of stagnant water suitable for breeding. In-migrants from regions where the diseases are endemic or where incidence is high may include infected individuals, thereby ensuring the transmission cycle. *Settlements which combine the conditions of vector breeding habitat and potential parasite pool in infected persons will require both special health treatment and habitat/vector control programs.* Correction of poor drainage is a first priority. The problem is not necessarily exclusive, of course, to low-income settlements.

B. ENVIRONMENTAL SURVEY AND MONITORING GUIDELINES

The guidelines presented below assume that a city about to undergo rapid growth, or already growing rapidly, will have limited financial and human resources for all urban sectors and a virtually infinite demand for existing resources. It is also assumed that there is recognition that environmental and monitoring data must be obtained in order to guide the attainment of minimum short-term and desirable long-range goals of environmental quality. Information for these purposes may be grouped into two general categories: 1) physical environmental and demographic data and 2) water and air quality data. In the first category the critical data pertain to water resources, climate, demographic movements, and public health. These are discussed in detail below. They are essential for the calculation of potential impacts of various kinds and levels of pollution, congestion, and general environmental deterioration. The appraisal of these impacts should be integral to the consideration of various policy and program options and to the formulation of planning objectives. The second category, environmental quality data, pertains to trends that require monitoring. Trends in ambient environmental quality--e.g., in levels of pollution--must be monitored in order to guide the implementation and administration of policies which contain environmental-quality goals. In particular, water and air quality (discussed in later sections) should be monitored. Other trends that may require monitoring include noise, disease vector populations, and food contamination.

1. *Physical Environmental and Demographic Data*

(a) *Hydrological and Water Resources Data*

At the earliest time possible the water resources available to an urban region and their hydrological characteristics should be surveyed. In regions with water scarcity such a survey is of highest priority. Needed hydrological data include:

1) total as well as temporary water demand, present and future
2) average and minimum surface-water availability
3) groundwater availability
4) maximum flood-flow and minimum flow
5) flood volume
6) water rights
7) water quality, surface and subsurface

Since the acquisition of this data will necessarily involve a survey of the entire watershed and drainage basin in which a city is located, additional data may also be included on irrigation use and projected demand, hydroelectric power potentials, and navigation. A useful presentation of the definition and design of hydrological and water resources

surveys for planning and development is found in Chapter V of the publication *Physical Resource Investigations for Economic Development, a Casebook of OAS Field Experience in Latin America* (OAS, 1969).

Within the present and projected future metropolitan area, drainage subsystems should be surveyed for the purposes of assisting the planning of storm and other run-off and of guiding decisions concerning the collection and treatment of human and other urban wastes.

Complementary data should be obtained on the various values of aquatic resources in downstream and receiving waters and on the importance of these downstream waters and their resources should be determined. If vulnerable downstream waters are important as shellfish grounds, they should be routinely monitored for fecal coliform. For highly productive fishing waters potentially susceptible to urban pollutants, baseline data on primary productivity should be obtained to provide a basis for interpreting trends in productivity which may be influenced by urban-derived pollution.

Groundwater surveys in the urban region should be designed to enable calculations of total availability and rate of recharge. In order to manage groundwater sources so as to prevent contamination by polluted surface waters, the surface areas of principal formations or zones charging aquifers with surface water should be identified. In limestone karst areas, special problems are posed due to the possible existence of subterranean streams and direct connections with surface-water flow. Pollution of groundwater in such zones has become a problem in the United States (DuMontelle et al., 1971).

In zones with high seismicity and earthquake danger, groundwater surveys which include drilling can be designed to obtain information on the engineering characteristics of the subsoil for predicting and assessing seismic hazards in order to guide zoning and the setting of earthquake-resistant building codes. The probability of subsidence following pumping also should be anticipated, and data should be collected to assess this hazard.

In aquifers near coastal zones, intrusion of saline water because of drop in hydrostatic pressure following pumping is a special hazard. Surveys should generate information needed to predict this kind of hazard for the purposes of managing the aquifer.

Lastly, an inventory of private and public wells should be made for purposes of evaluating health hazards posed by their possible contamination with polluted run-off.

b) *Meteorological Data*

Meteorological data is required to determine urban run-off as well as to predict and evaluate air pollution. In addition to rainfall, temperature, and wind data, stations should obtain information on insolation and

atmospheric stability, important determinants of photochemical smog generation. If conditions are conducive to the occurrence of temperature inversions, temperature records should be obtained at various altitudes. Antennas or towers as well as hills can be used to situate recording instruments. Synoptic photographs taken from a high point above the city, if such elevation exists, can complement meteorological data and greatly assist in the interpretation of air movements over the city at different seasons. These data can be used in planning the location of facilities such as hospitals and schools in order to avoid sites where topographic and climatic influences concentrate air pollutants. The data can also be used as a factor in decisions for location of residential zones and heavy industry.

Wind data from existing stations may be deficient for air-quality assessment purposes. New stations or additional data may be required in order to know seasonal variations in wind direction and wind speed. Both wind and surface sensors require carefully selected locations with open exposure. For example, distance between the instruments and any obstruction should be a minimum of ten times the height of the obstruction. The thermograph instrument should be situated over a grassy area and not over a concrete surface.

c) *Public Health Data*

The critical nature of epidemiological, morbidity, and mortality data for assessing the impact of various pollutants and environmental changes on public health was clearly demonstrated in the case study of Seoul. Data are needed from both monitoring and surveillance programs, which in the public health field have specific connotations. WHO has proposed the following definitions (WHO, 1972, p. 269):

"*Monitoring* is the making of routine observations on health and environmental parameters, and the recording and transmission of these data."

"*Health surveillance* is the collation and interpretation of data collected from monitoring programs and from any other available sources, with a view to the detection of changes in the health status of populations."

In the WHO publication *Health Hazards of the Human Environment* (1972) a major 60-page section is devoted to the subject of surveillance and monitoring of public health. Topics covered include the role of epidemiology and health indices in evaluating environmental hazards, communicable diseases, radiation, nutritional indices, indices of vectors, congenital problems, drug reactions, mental disorders, data handling and assessment, and systems analysis and control. It is recognized that the compilation and digestion of data on all factors in the human environment that influence human health are not feasible. Data needs must be carefully defined and restricted to those factors likely to have a significant impact.

With respect to morbidity and mortality data, WHO recommends that statistics should be compiled promptly, the breakdown should be in terms of small population groups, and the period covered by statistics should be short--on a daily, weekly, or monthly basis. These data should be supplemented by data collected from ad hoc inquiries on a sampling basis.

d) *Socioeconomic Data on In-Migrants and Squatter Settlements*

If poor in-migrants account for a significant part of a city's population growth and in-migration rates are high, special monitoring programs should be devised. These can be combined with social and economic surveys, the data from which are equally essential for guiding and modifying, when necessary, policies concerned with dwellers in low-income housing and their living environments.

While it probably is impossible to predict future volumes of in-migration--assuming there is no control of this phenomenon--carefully designed surveys and research can greatly assist the formulation of housing and other policies that bear on in-migrants. The technological unemployment and other impacts of rural farm modernization and mechanization should be assessed. This analysis ought to address national as well as specific rural-urban population movements. Periodic surveys should be undertaken to provide for the determination of trends.

For migrants already in the city and for new arrivals, purposive surveys should be undertaken that are designed to determine differences in motivations and in adjustment among different categories of migrants. Possible categories include young single men and women, young heads of households migrating with their nuclear families, and older heads of households. Each category should include persons with various levels of education and of different rural origin. Surveys should attempt to determine why the migrants moved as well as the conditions under which they might have been willing not to move. Finally, surveys should attempt to determine patterns of job and housing mobility.

Data on squatter settlements, as distinct from in-migrants in general, might focus on variations within these settlements, the functions they serve for their residents, and the socioeconomic characteristics of their residents. In connection with planning public transportation as well as relocation of such settlements, it would be important to obtain data on squatter residents concerning job locations, mode of commuting, second and third earners in families, and other supplementary employment.

Special attention should be given to collecting data on the public health status and needs of low-income citizens, as has been mentioned in the guidelines concerning squatters and slums.

2. *Air and Water Quality*

a) *Air Quality Monitoring and Assessment*

For a city in the process of rapid growth, the prediction of future air quality requires more comprehensive and sophisticated data than will be available initially. First priority should be given to obtaining basic data on meteorology (already mentioned), emissions, and existing air quality. Fixed air-quality monitoring stations should be situated in the congested central business district, in and near major concentrations of industries, and at several locations in residential areas. If resources permit, air quality in important farming areas contiguous to the city or near industrial zones should be monitored. As industrial and other point-source emissions increase, emissions inventories should be undertaken to provide a basis for projecting atmospheric pollutant-loading.

An excellent resource document for guiding the design and operation of an air-quality monitoring program was published by NATO's Committee on the Challenges to Modern Society (NATO/CCMS, 1971). That document presents guidelines for the assessment of air quality and the results of two pilot studies of air quality, one in St. Louis, Missouri, U.S.A., and one in Ankara, Turkey. Salient points of the document are summarized below; however, no attempt is made to make a comprehensive summary. A second useful document is EPA's *Guideline for Air Quality Surveillance Networks* (EPA, 1971). That small publication was intended to assist states in the design of minimal surveillance networks in order to judge compliance with ambient air-quality standards, activate emergency control procedures to prevent air pollution episodes, observe pollution trends, and provide a data base for the evaluation of various influences on air quality.

The procedure proposed by CCMS for monitoring and assessing air quality consists of four tasks: 1) collection of data on emissions, meteorology, and air quality; 2) verification of a diffusion model using measured air quality; 3) forecasting future emissions; and 4) estimation of future air quality. The methods and procedures set forth are specifically aimed at urban areas.

Collection of data on emissions can be done by a number of techniques, from the simple to the complex. Simplest is the review of published data. This was done for the Seoul case study. Next in complexity is the use of the Rapid Survey Technique, which incorporates available data with a survey of 50 to 100 major point-sources. Seoul was to carry out a Rapid in late 1973. The technique is useful when point-sources contribute the majority of emissions. Two full-time persons can carry out such a survey in 6 to 8 weeks in a city of one-half million to two million inhabitants. More complex is the comprehensive survey, which obtains additional information on stack diameter, temperature, velocity, and height above ground level.

Extensive visits and questionnaires are used. Emissions inventories generally are made for at least five major pollutants: particulates, SO_x, CO, NO_x, and hydrocarbons.

Considerations relevant to the design and operation of an air-quality monitoring network are: 1) appropriate monitoring systems, 2) instruments and methods, 3) number and location of sampling sites, 4) sampling duration and frequencies, and 5) data-handling systems. Monitoring may be carried out by fixed or mobile sampling networks. It may use continuous monitors or integrated samplers. Fixed sampling has the advantage of providing directly comparable information while mobile sampling allows samples to be taken at many different sites and thus provides better information on geographical variations. The CCMS guidelines discuss in detail the advantages of continuous and integrated sampling, selection of instrumentation and methods, and the comparative costs of various methods for measuring sulfur dioxide and particulates.

The number of stations and their locations in an urban area will depend upon expected pollutant concentrations and degree of human exposure. A rough indication of the minimum number of sampling stations for a given area is shown in Figure 4.

The information required for selecting sampler location is the same as that for determining network size: maps depicting topography, rainfall and temperature distribution, population density, industrial and other economic activity, general land use, and location of pollution sources. EPA proposes the following guidelines (EPA, 1971):

1) The priority area is the zone of highest pollutant concentration within the region.

2) Close attention should be given to densely populated areas within the region, especially when they are in the vicinity of heavy pollution.

3) For assessing quality of air entering the region, stations must also be situated on the periphery of the region.

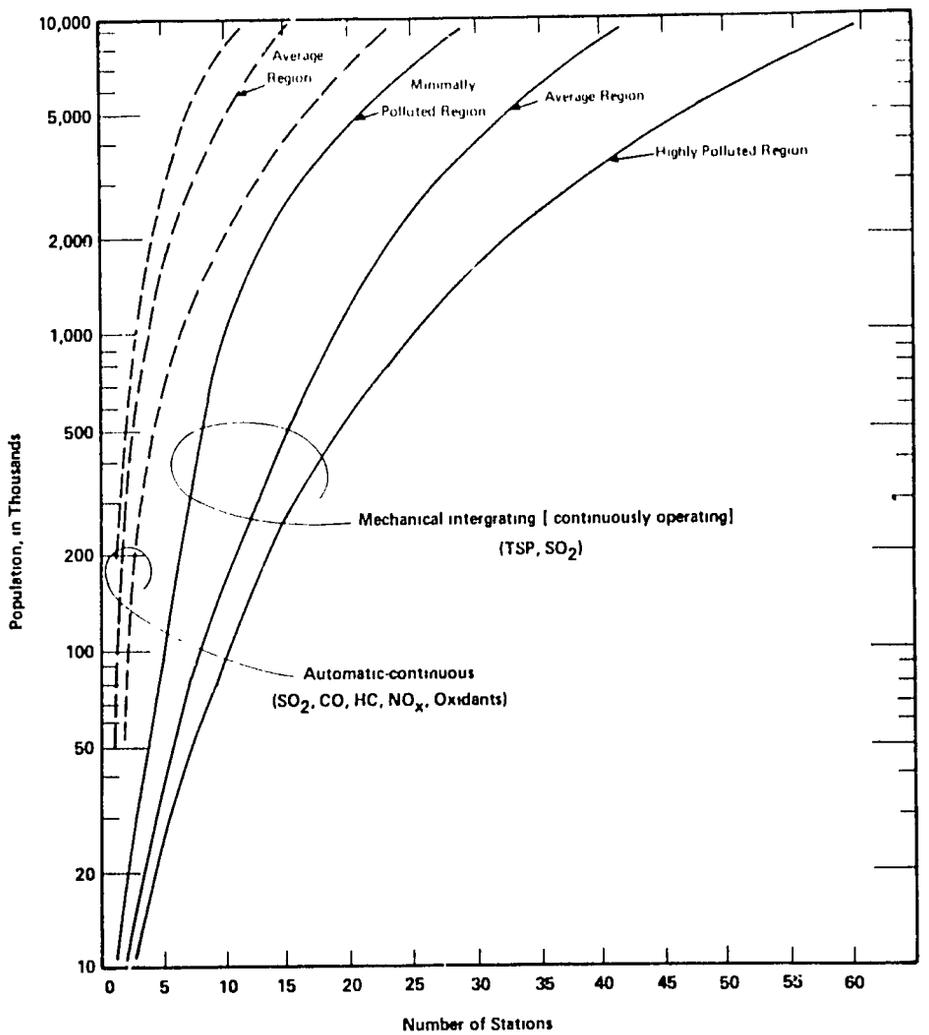
4) For determining the effects of future development on the environment, sampling should be undertaken in areas of projected growth.

5) A major objective of surveillance is evaluation of the progress made in attaining (or maintaining) the desired air quality. Sampling stations for this purpose should be strategically located to facilitate evaluation of the implemented control tactics.

6) Some information on air quality should be available to represent all portions of the region.

For predicting future air quality, models have been developed for computers. These describe the dilution and dispersion of stable pollutants. Models which can predict the photochemical and chemical reactions which couple to produce secondary pollutants have not yet been successfully developed. Within certain limitations models can be used for estimating air quality for the long-term (20 years) as well as for immediate and near-term periods.

Figure 4 Regional Population Versus Number of Stations



Source: NATO/CCMS, 1971, p. 34.

Projections of air pollution emissions are a key input to modeling future air quality. To make projections, forecasts are needed on total population and distribution, industrial activity, fuel use, transportation activity, solid-waste generation and disposal, and degree and extent of air pollution control. Such forecasts can be obtained from transportation studies and physical and master planning studies.

b) *Water Quality Monitoring and Assessment*

Guidelines for monitoring water quality of streams have been prepared by the U.S. Federal Water Pollution Control Administration (Kittrell, 1969), and analytic methods are standardized (APHA, 1971). Useful information on water quality instrumentation is contained in a collection of papers by the Instrument Society of America presented at various international symposia (Scales, 1972). Two papers on the design of water-quality monitoring systems and measurement programs appear in the recent publication *Design of Environmental Information Systems* (Mancy, 1973; Wilson, 1973). Monitoring parameters should include coliform counts (including fecal coliform), temperature, turbidity, pH, and organic and inorganic chemicals which may be significant.

The first priority is the monitoring of raw water at purification plant intakes and at various stages in the treatment plant. Appropriate instrumentation and measurement normally are integral to the system.

For surface-water supplies, additional monitoring at various points in the upstream drainage system should be carried out for the purposes of guiding the operation of purification plants and detecting needs to control factors in the watershed which adversely affect quality--factors such as agricultural run-off and erosion. Agricultural run-off may also affect urban groundwater. If so, monitoring of this source should include measurement of agricultural chemicals inimical to human health. Toxic chemicals even though ordinarily considered biodegradable may pollute groundwater if downward percolation of surface-water to aquifers is rapid. Because of the absence of microbiological life as well as low temperatures in aquifers, these chemicals may not be metabolized or otherwise degraded into less toxic compounds once they have entered the aquifer.

Additional monitoring needs will be determined by hydrological characteristics, expected pollution, and water resources values in the urban region and of downstream or underground receiving waters. For cities such as Seoul, which depend upon major rivers exposed to urban wastewater for their drinking water supply, it is clear that baseline water-quality surveys should not be postponed until pollution becomes obvious. In Seoul, baseline water-quality data were not obtained until the city had attained a population of 6.0 million. Had data been

obtained earlier and been followed by systematic monitoring, more timely information concerning trends in the Han River's quality would have been available to guide decisions concerning the requirements for expansion and protection of Seoul's supply of drinking water.

The design and operation of a water-quality monitoring program must be guided by a clear statement of the program's objectives. Water-quality monitoring objectives generally fall into two broad categories: 1) the measurement of water quality at a single point, or 2) the measurement of water quality throughout a reach of water as it travels downstream.

Water-quality measurements at a single point may have a number of objectives: to establish a baseline record of water quality; to investigate the suitability of a source for municipal, industrial, or other water supply; to monitor water supply from day to day; to monitor the effects of waste discharges; or to investigate suitability for propagation of aquatic life or for recreational use. The measurement of water quality at a number of points on a stream may be undertaken to determine patterns of pollution downstream from waste discharges and their effect upon water uses; to determine characteristics and rates of natural purification of streams; to project the effects of pollution; to estimate reduction in waste loads necessary to meet water-quality requirements; and to determine existing water quality before some change in conditions such as new or increased waste discharge or impoundment.

The definition of the objectives will determine the location of sampling stations, choice of sampling procedures, sampling frequencies and duration, and sample analyses.

Since, as mentioned previously, *the level of human exposure to untreated surface waters is normally high in developing countries, especially in the tropical latitudes, monitoring of quality factors important to public health should be undertaken of rivers or streams that are known or suspected to be dangerously polluted, and which are used by riverside dwellers for washing, bathing, and as a source of domestic water.* Obviously, alternative water supplies must be provided if monitoring reveals dangerous levels of pollution for which there is no immediate control.

Decisions concerning the monitoring of water sources used by industry will depend upon the type and concentration of industry and the number and kinds of industries to be provided from a single source of water. Industrial water-quality requirements vary considerably (Table 13).

Monitoring of industrial wastewaters for levels of permissible pollutants will depend upon the resource values of receiving waters. A detailed compilation of research published in English on the effects of various kinds and concentrations of industrial effluents on aquatic life can be found in *Water Quality Criteria Data Book, Vol. 3: Effects of Chemicals on Aquatic Life* (EPA, 1971).

Table 13 Point-Of-Use Water Requirements for Selected Industries

Characteristic	Power generation	Textile	Pulp and paper	Chemical process	Petroleum	Food	Soft drink	Cement
Hardness ($CaCO_3$)	0 20*	25	100	250-900	350	250	‡	‡
pH, units	8-10*	2 5-10 5†	6-10	6 2-8 7	6-9	6 5-8 5	‡	7†
Calcium, mg/l	0		20	60-100	75	100	100	.....
Chlorides, mg/l	No problem		200-1,000	500	300	250	500	250
Manganese	0 01-0 3	0 01-0 05	0 05-0 1	0 1-0 2		0 2	0 05	0 5
Iron, mg/l	0 01-1*	0 1-0 3	0 1-0 3	0 1-0 3	1	0 2	0 3	25
Color units	No problem	5	10-30	20	No problem	5	10	No problem
Alkaline ($CaCO_3$)	40-140			125-200		250	85	400
Suspended solids	0-10	5	10	5-30	10	10	0	500

*A function of boiler pressure.
†Depending upon operation (sizing, bleaching, scouring, etc.).
‡Controlled by treatment for other constituents.

Source: World Bank, 1973.

That publication can be used as a guide for assessing the potential effects of possible pollutants on known aquatic organisms. However, local aquatic resource surveys and research will be required to obtain information on local aquatic biology and ecology and the effects of various effluents on aquatic life. Especially in tropical and subtropical regions, comparatively little information exists on aquatic ecosystems and their resources, whether freshwater or marine, and on toxic effects of various kinds of chemicals in the effluent waters of different industries. Research on estuarine productivity as affected by waste discharges on the Texas coast, U.S.A. (Davis and Eckenfelder, 1972), employed laboratory principles and methods that, the authors state, may be applied to any aquatic ecosystem.

In Southeast Asia, brackish-water fishponds are particularly susceptible to industrial as well as municipal pollution. Although their contribution to total fish production is very important, toxicity tests on cultivated species such as *Chanos chanos* (milkfish), *Tilapia* spp., and prawns have not yet been undertaken, nor can research results from high-latitude countries be used as a reliable guide. Laboratory toxicity-test results will be essential for determining monitoring needs as well as pollution control goals.

Estuaries affected by urban pollution require special monitoring programs in order to guide management, conserve high productivity, and avert public health problems, especially from the ingestion of shellfish contaminated by human disease pathogens.

Many commercially valuable species fished on the high seas live in estuaries during the postlarval and juvenil stages, at which times they are especially sensitive to salinity, temperature, and various pollutants. Shrimp are an example. Tropical estuarine biota live much closer to their thermal maxima than their temperate counterparts (Moore, 1972). Increases of less than 3°C. can be widely destructive. Normal biota tend to be replaced by less desirable species such as blue-green algae, which may produce materials toxic to other organisms. In tropical waters this is believed to be related to ciguatera poisoning in man, as a consequence of ingesting fish which have concentrated toxins in their flesh (de Syla and Hine, 1970). Thus, monitoring of valuable estuaries that are subjected to organic or thermal pollution should receive high priority, although control of these forms of pollution is of first priority.

Laboratory analyses are a major factor in the cost of a water-quality monitoring program. Tables 14, 15, and 16 summarize overhead and analytical costs in terms of time and of skill levels required for various analyses. These estimates pertain to conditions in the U.S.A. The most difficult indirect cost to assess is instrumental usage. An inexpensive instrument such as a $500 pH meter with a projected useful life of 5 years and requiring little maintenance may be amortized over the entire 5-year period

Table 14 Indirect Costs Incurred in Analytical Operations

Phase	*Overhead Factor**
Before Analytical Work	
Request for Services	Administrative
Preliminary Discussion	Administrative, Consultative
Telephone Correspondence	Clerical
Project Design Parameters Number of samples Location of sampling points	Consultative
Sampling Travel Sampling equipment Sample delivery	Technical
After Analytical Work	
Reporting Review of data Computer services	Consultative, Technical Clerical
Preparation of report Follow-up	
Miscellaneous Instrumental Laboratory	Technical

*Exclusive of rent and utilities

Source: Kroner, 1972, p. 192. Reproduced with permission of Instrument Society of America, Pittsburgh, Pennsylvania.

Table 15 Skill-Time Rating of Standard Analytical Operations

(Simple instrumental, volumetric, and gravimetric)

Measurement	*Skill Required** *(Simple Instrumental)*	*No/Day*
pH	1	100-125
Conductivity	1	100-125
Turbidity (HACH 2100)	1	75-100
Color	1	60-75
Dissolved Oxygen (Probe)	1, 2	100-125
Fluoride (Probe)	1, 2	100-125
	(Simple Volumetric)	
Alkalinity (Potentiometric)	1	50-75
Acidity (Potentiometric)	1	50-75
Chloride	1	100-125
Hardness	1	100-125
Dissolved Oxygen (Winkler)	1, 2	75-100
	(Simple Gravimetric)	
Solids, Suspended	1, 2	20-25
Solids, Dissolved	1, 2	20-25
Solids, Total	1, 2	25-30
Solids, Volatile	1, 2	25-30

*SKILL REQUIRED

*1, Aide with minimum training; 2, aide with special training or professional with minimum training.

Source: Kroner, 1972, p. 194. Reproduced with permission of Instrument Society of America, Pittsburgh, Pennsylvania.

Table 16 Skill-Time Rating of Standard Analytical Operations

(Simple colorimetric, complex volumetric or colorimetric, and special instrumental)

Measurement	*Skill Required** *(Simple Colorimetric)*	*No/Day*
Nitrite N (Manual)	2	75-100
Nitrate N (Manual)	2	40-50
Sulfate (Turbidimetric)	2	100-125
Silica	2	100-125
Arsenic	2, 3	20-30
	(Complex, Volumetric or Colorimetric)	
Biochemical Oxygen Demand	2, 3	30-40
Chemical Oxygen Demand	2, 3	25-30
Total Kjeldahl Nitrogen	2, 3	25-30
Phosphorus, Total	2, 3	50-60
Phenol (Dist'n only)	2, 3	20-30
Oil & Grease (Soxhlet)	2, 3	15-20
Fluoride (Dist'n)	2, 3	25-30
Cyanide	2, 3	10-15
	(Special Instrumental)	
Metals by Atomic Absorption (No preliminary treatment)	2, 3	150
Metals by Atomic Absorption (With preliminary treatment)	2, 3	60-80
Pesticides by Gas Chromatograph (Without cleanup)	3, 4	3-5
Pesticides by Gas Chromatograph (With cleanup)	3, 4	2-4

*SKILL REQUIRED

*2, Aide with special training or professional with minimum training; 3, experienced analyst, professional; 4, experienced analyst, professional, specialized.

Source: Kroner, 1972, p. 195. Reproduced with permission of Instrument Society of America, Pittsburgh, Pennsylvania

at a rate of less than 30¢ per day. Conversely, a $50,000 spectrograph requiring expensive maintenance, amortized over a similar period, may cost the laboratory more than $30 a day to operate. Under any circumstances, the amortization rate of the instrument is important, and the rate, of course, is dependent upon the user's experience and judgment. Expenses accruing from use and maintenance may be minimized to a certain extent by competent operation and careful upkeep.

3. *Rationale for Environmental Surveys and Monitoring*

The Seoul case study clearly illustrated an important principle: the achievement and maintenance of environmental quality in a situation of rapid urban growth will require a good environmental data base as well as monitoring of important trends in the urban environment. Baseline data is essential for setting environmental quality goals. Monitoring data is especially needed in a rapid growth situation in order to provide a basis for appropriate remedial actions, when necessary, and to measure the success of environmental management actions. *Cities should not wait until pollution or other environmental deterioration is obvious before implementing monitoring and baseline data collection. Water quality in particular should be measured and monitored as early as possible, even before pollution is suspected.* Changes in the status of environmental quality are liable to occur in a stepwise manner rather than incrementally, which has important implications for air- and water-quality parameters significant to public health.

The importance of environmental baseline data for setting urban environmental quality goals, even if these are to be temporarily subordinated to economic development imperatives, may be difficult to translate into budgetary justification. Ample documentation, however, is provided by Tokyo and other large cities in Japan (and other countries) of the steady and hazardous degradation of water and air quality to the eventual detriment of human health. Nevertheless, while the known synergistic and incremental impacts of serious ambient pollution such as in Tokyo demonstrate the ultimate consequences of uncontrolled pollution, they are not easily translated into elements of judgment for determining the justification, timing, content, and scope of an urban environmental monitoring program in a rapidly growing city.

The justification for monitoring is best embodied in a policy which sets urban environmental quality goals, whose definition and attainment is defined in terms of over-all social well-being. The burden of justifying monitoring should not fall on the technicians and scientists charged with water supply and distribution, wastewater and human waste collection and treatment, solid-waste disposal, transportation, and traffic. A deterioration in environmental quality attributable to their areas of responsibility could

be interpreted as a program failure, hence responsible officials are not likely to emphasize the seriousness of trends which ought to be monitored. Further, the cause and effect relationships of various forms of ambient pollution and the various associated damages or costs are, for the most part, not yet well enough understood. Highly specific knowledge would be needed on the physical, biological, social, and economic impacts of pollutants, singly or in combination, and in the short term and the long term. Hence, the purely economic or scientific basis for monitoring many parameters cannot be precisely developed by scientists or technicians.

The effect on humans of highly toxic pollutants such as mercury, lead, and certain organo-phosphorus compounds is well known. Hence, their control or monitoring is justifiable and is independent of the particular stage of economic development. This also holds true for waterborne disease pathogens, a more important threat. Knowledge is imperfect, however, on the effects of sublethal ambient pollutants, whether for long- or short-term periods. Furthermore, the causal relationships between sublethal pollutants and their subtle effects on humans, materials, or plants are confused by other related influences. For example, an individual's smoking habits influence his physiological response to carbon monoxide pollution. Anemia related to parasite infestation may also exacerbate the effects of carbon monoxide pollution. Until better information develops on the effects of more subtle forms of pollution and environmental deterioration, the decision to monitor these phenomena will have to be based primarily on the establishment of environmental goals whose maintenance or attainment a city considers desirable.

It is self-evident that at some point in a city's growth air and water pollution monitoring programs should be initiated in order to avert major public health problems such as generalized illness or death. The decision as to the timing and design of a monitoring program to safeguard public health, if this is the main justification, must take into account a number of variables: general status of public health; known effects on human health of different air and water pollutants; projected pollutant-loadings in the air and water; and physiographic controls on the movement and dispersion of pollutants. These same considerations would be taken into account in the formulation of a broader-purpose monitoring program designed to ensure the attainment of air and water quality goals and other environmental standards and to help guide planning and development to meet these standards. The fact is that the justification for environmental monitoring, coupled with monitoring of relevant demographic and public health inicators, raises the key questions posed by the environment versus development debate. Is environmental deterioration an inevitable sacrifice of urbanization? Can deterioration be halted at some critical stage? Can it be reversed? Is it more costly in terms of time or

money to prevent environmental deterioration than to remedy it after development goals have been attained? What are the social and human costs resulting from the public health impact of air, water, and noise pollution at various levels? Smaller but growing cities not yet committed to unalterable growth patterns (or compelled by existing patterns) can and should seriously consider these questions.

III. THE IMPACT OF RAPID URBANIZATION ON SEOUL'S ENVIRONMENT: SUMMARY OF A CASE STUDY

A. INTRODUCTION

A comprehensive review of Seoul's urban environmental problems, the first of its kind, was undertaken in 1972-1973 by nine social and physical scientists and engineers. Sponsored by the Smithsonian Institution, this multidisciplinary study was carried out for the U.S. Agency for International Development in order to understand better the environmental impact of rapid urbanization as a basis for formulating urban environmental guidelines. The topics studied were: public health, water pollution, air pollution, solid waste, transportation, squatter communities, a satellite city attempt, and urban pests (insects and rodents). Technical reports resulting from short visits were synthesized in two workshops, one in the U.S.A. and one in Seoul, Korea. This is a summary of the resulting document, "The Impact of Rapid Urbanization on Seoul's Urban Environment" (Smithsonian Institution, 1973).*

In 1973, Seoul contained approximately 20 percent of the Republic of Korea's population. Average population density in its 613 square kilometers was slightly over 10,000 per km^2. During the course of an 18-month survey of Seoul's environment, the city's population increased by over 300,000.

Seoul's estimated population in 1973 of 6.3 million was attained at an extraordinarily fast rate, much faster than planners projected. In 1962, when the city had slightly over 3 million people, its 1973 population was projected to be only 3.8 million, a gross underestimation. In fact, the city has been almost doubling in size every ten years since 1945, and its growth curve has not levelled significantly. Annual growth rates averaged over 9 percent during 1966-1970 (Table 17). The planning projections in 1973 anticipated a leveling off of the growth rate so that by 1981 Seoul will have only 7.5 million. But to this total will be aggregated another 2.5 million persons within 45 kilometers from the city's center but outside of city limits.

The rapid growth of Seoul is of great economic significance to Korea. Until recently, Seoul has dominated industrial development--45 percent of the national production

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*The full case study is a working document limited to internal use by the City of Seoul and the U.S. Agency for International Development.

Plate 6. Residential section, Seoul. Dense housing and narrow lanes are typical of residential areas in many cities of the developing world.

came from Seoul in 1966. Industry is now dispersing and will continue to do so, but Seoul will remain the primate city, dominating political and economic decision-making. Thus, the development of the Republic of Korea is essentially related to the capacity of its major urban-regional center, Seoul, to function effectively while growing rapidly.

Table 17 Population of Seoul, Korea, 1945 to 1973

Year	Total	Growth Rate, 1960's (%)
1945	901,371	
1950	1,693,224	
1955	1,574,868	
1960	2,445,402	-
1961	2,577,018	5.38
1962	2,983,324	15.77
1963	3,254,630	9.09
1964	3,424,385	5.22
1965	3,470,880	1.36
1966	3,805,261	9.63
1967	3,969,218	4.31
1968	4,334,973	9.21
1969	4,766,928	10.20
1970	5,536,377	13.70
1971	5,850,925	
1972	6,076,143	
1973	6,300,000 (est.)	

Source: 1945 to 1970, Seoul Metropolitan Government, 1971, *Seoul Statistical Yearbook*; 1971 to 1973, City of Seoul estimates.

While there is no single way to assess Seoul's--or any city's--effectiveness, or of even satisfactorily defining effectiveness,* it is possible to inventory the

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*Alonso (1971) discerned four major urban policy objectives in the United States: efficiency, equity, environmental quality, and life style. For other countries he suggests other objectives, including the integration of implementation and planning of national economic goals and the creation of national identity, both of which could be seen as applicable to Seoul. The achievement of such goals would be one way of measuring a city's effectiveness or performance.

available data and review the major problems being experienced in the course of rapid growth.

The study reviewed the environmental problems that pertained to the situation in Seoul during 1972-1973. A primary concern was to characterize adequately and describe a number of environmental problems related to rapid urbanization in order to provide a better basis for planning and policy making and for subsequent further study of these problems. An economic analysis of the problems studied was not made.

The resulting portrait of Seoul's environment was rough and, in places, vague for lack of good information. No original research or systematic sampling surveys were carried out by the U.S. scientists. Korean counterpart scientists did not collaborate directly in defining the study problem or in interpreting and drafting initial study documents. However, Koreans reviewed the draft and their comments, elicited during a workshop, were incorporated into the final version of the case study as well as into the present summary.

As better information continues to be developed, there will emerge a better basis for environmental assessment in Seoul. But the outlines of Seoul's various environmental problems were sufficiently clear to justify intensification of the city's efforts to confront these problems. Where problems were only vaguely delineated because of lack of data, there was obvious need for better information.

B. PRINCIPAL ENVIRONMENTAL PROBLEMS IN SEOUL

Two of Seoul's most serious problems stem from rural traditions and practices which continue to be used in the city but are unsuited to crowded urban conditions: the *ondol* system of heating and cooking (described below) and the handling and disposal of night soil. The first pollutes the air, both in the dwelling and outside, while the second pollutes water and, indirectly, food. Both constitute important public health hazards. Squatters and their settlements in Seoul pose major problems--as in almost all developing-country cities--but the city did not perceive them as environmental in nature. Squatter settlements are, nevertheless, poor living environments, although squatters do attempt to improve them. Finally, pollution from industry and various kinds of pollution from the transportation system in Seoul constitute complex problems which are difficult to assess but for which more and better information is being developed. Solid-waste handling and disposal are being carried out well. However, a shortage of disposal sites is beginning to be felt. Contamination of food by pesticides is a minor problem as compared to parasite contamination.

1. *The Ondol*

This system for heating and cooking is used in Korean homes at virtually all income levels. It is cheap and comfortable. The hot exhaust gases of kitchen burners are conducted through a system of flues that run almost horizontally under the floors of elevated sleeping chambers, and thence vertically through a number of chimneys. In the country, wood and charcoal are burned, but in Seoul standard-sized, cylindrical, anthracite briquets, manufactured in some twenty factories, are burned.

The slow combustion of the briquets produces carbon monoxide which may contaminate kitchen air and sleeping chambers, particularly when faulty construction of flues and floors results in leaks. In rustic country dwellings, openings in walls result in better ventilation and diminish the danger of CO poisoning. In more tightly built city dwellings this is not the case. Because the affinity of hemoglobin for CO is 200 times greater than for oxygen, uptake of carbon monoxide reduces oxygen-carrying capacity of the blood, exacerbating heart disease and producing physical and mental sluggishness. Low blood hemoglobin levels, often traceable to parasite infection, also aggravate the effects of carbon monoxide pollution. Occasional death and illness from sublethal CO poisoning can result; the extent of illness in Seoul is not known.

Another impact is the enhanced probability of tuberculosis transmission. Frequent air turnover would work against the efficiency of the *ondol* heating system. The relatively stagnant warm air of houses that are well sealed results in a good medium for airborne tubercule bacilli.

The *ondol* is also a major source of ambient air pollution, generating 38 percent of all combustion-derived emissions. Further, the briquets produce about 25 percent ash by weight, which results in a very considerable disposal problem. Of an average of 7,000 tons per day of solid waste that was collected in Seoul in 1973 had to be disposed of in landfills, roughly 60 percent was briquet ashes. Also, the making, handling, and burning of anthracite generate almost 30,000 metric tons of dust per year (Table 18).

The very immediate and real problem of where to dispose of briquet ash must be confronted soon. The need for an inventory of available, suitable disposal and/or landfill sites was recognized. Conversion from anthracite briquet to gas should be seriously considered. A possible source is methane gas produced in the decomposition of human wastes. But quantity produced is relatively small and existing technologies are still to be developed for domestic fuel purposes.

Table 18 Estimated Yearly Total Fuel Combustion Pollutants, Korea, 1972. (In metric tons.)

Pollutant		Anthracite	Gasoline	Fuel Kerosene	Diesel	Bunker-C	Totals by Pollutant
SO_x	m.t.	38,304	390	55	2,257	78,586	119,593
	%	32	*	*	2	65	27
NO_x	m.t.	24,408	8,033	4,982	5,370	21,508	64,140
	%	36	12	8	8	34	14
CO	m.t.	74,480	104,208	188	2,335	1,792	183,003
	%	41	57	*	1	1	42
HC	m.t.	7,980	14,285	138	11,984	689	35,077
	%	23	41	*	34	2	8
Dust	m.t.	28,728	477	305	5,720	3,860	39,090
	%	74	1	1	15	10	9
Totals-Fuel		172,900	127,394	5,668	27,666	106,435	440,063
	%	39	29	1	6	24	100

*Less than 1%

Source: 1972 study by the Metropolitan Government of Seoul, the Ministry of Health and Social Welfare and Yonsei University.

2. *Night-Soil Collection and Disposal*

The prevalence of enteric infections, both acute and chronic, in the Seoul metropolitan area (80 percent rate of infection) is closely linked to the conditions under which the collection of night-soil and its disposal takes place. A sanitary collector sewer system did not yet exist in Seoul, although it was being planned. Different methods of handling and disposing of human wastes and their proportions to total production are shown in Table 19.

Table 19. Night-Soil Treatment in Seoul, 1971 and 1973

	kiloliters/day 1971	1973
Total night soil	5,041	6,356
Total amount treated	2,624	4,269
Disposal/treatment tank	776	1,880
Fermentation & discharge into Han River	1,643	1,521
Wet-oxidation treatment	-	600
Direct use as fertilizer	205	268

Source: Unpublished data provided by the City of Seoul.

Human excreta was periodically collected from residential holding tanks either by laborers with buckets who discharged these into trucks or by trucks equipped with vacuum pumps and hoses. With the latter method, there was less accidental spillage during transfer. Besides spillage during transfer, pollution occurred at the disposal site, where the night-soil ferments in large basins but at temperatures too low to kill roundworm (*Ascaris*) eggs. These parasites may contaminate crops fertilized with raw night-soil or with the dried product from the fermentation basins, which was sold as fertilizer, although in decreasing amounts. Groundwater in these areas was contaminated, threatening the health of people who obtained domestic water from shallow wells. A portion of the total night-soil collected was discharged into the Han River after fermentation, thus contributing to its pollution. It was illegal to discharge raw night-soil into the Han, however.

Food was contaminated by various avenues: in the fields by raw fecal matter or by the dried product which may have viable parasite eggs, at the market by contaminated water, or in food processing industries with poor sanitation.

Pollution of the Han by night soil, among other pollutants, essentially rules out its recreational value and, perhaps more seriously, generates special treatment problems for the city's water supply, which is pumped from the Han at five intakes and is run through treatment plants. The cost of the Han River pollution was high both in terms of lost recreational opportunities and the cost of strategies to protect the water. In large part because of the purification problems, the city had decided to move its water-supply intake upstream to a damsite where the water is as yet unpolluted. Until then, treatment costs were expected to rise relative to deterioration in the quality of the raw water.

Although the Han was known to be contaminated with human wastes, this element of water quality (i.e., MPN coliform) was not being analyzed. The 1972 BOD levels indicated that organic pollution-loading was not as high as would be expected, although seasonal variation was considerable; and, not unexpectedly, BOD increased downstream. Systematic measurements of the Han River's water quality were not made until the start of 1969, so baseline data on water quality are only recently available.

The City of Seoul was dealing with the night-soil problem on several fronts. Collection from holding tanks was increasingly handled by vacuum pumps and hoses; up to 85 percent of the dwelling units eventually were to be serviced in that way, but excessively narrow streets will prevent servicing the remaining 15 percent. The construction of six wet-oxidation, or Zimmerman, plants for combustion of night soil was projected. One plant was already in operation. The six plants will have a 3.6 million/liter/day capacity and gradually will eliminate the settling and fermentation basins. It was planned that eventually sanitary collector sewers and treatment plants would replace the truck collection/wet-oxidation combustion system. The Zimmerman plants would then be converted or moved elsewhere. The composting of night soil for later use as agricultural fertilizer was an alternative that had been rejected on economic grounds because of transportation and handling costs and competition from chemical fertilizers.

Some pollution from domestic wastes entering the Han River will be eliminated upon the 1974 inauguration of a sewage treatment plant near the confluence of the Han River and the Chong Gye Chun tributary, whose flow will be diverted into the plant before discharge into the Han. In lieu of a collector sewer network, the natural drainage system of the Chong Gye Chun (and other tributary streams draining the city) has been gradually converted into a sewer. One of its branches has been totally paved over in downtown Seoul. The decision in 1966 to build this $8.76 million plant was based in part upon the need to

protect the water supply for downstream intakes. Only three years before that decision, a feasibility study for a $9.6 million downstream intake-purification plant had concluded that Han pollution would not seriously affect the operation. Later, however, BOD levels ranging from 100 to 300 mg/l and high coliform counts (maximum MPN of 54,000/ml) in the Chong Gye Chun argued heavily for treatment of its flow to protect downstream intakes.

An educational campaign to make people more sensitive to the Han pollution problem was planned in 1973, and was to be aimed particularly at riverside settlements.

Despite these various efforts, the Han seemed destined to receive heavy loads of pollutants until all the city's wastewaters are diverted into treatment plants. Justification for total treatment of the city's wastewaters should include the aesthetic and recreational values of the Han as well as its value as a source of domestic and industrial water to downstream users and to Seoul. The health and productivity of the Han estuary should also be a criterion.

3. *Industrial Pollution*

Industrial pollution was judged to be contributing very substantially to total pollution in Seoul, but almost no information had been collected. There was no monitoring program for emissions, although a Rapid Survey inventory of emissions undertaken in late 1973 will have helped correct this deficiency. In 1972 there were 4,300 registered industries and enterprises in Seoul subject to emissions controls as set forth in the 1972 Public Nuisance Control Law. Space heating plants in large buildings accounted for 1,027 of the total.

Because most industry was located in the downstream portion of Seoul, along the An Yan River, industrial water pollution does not [illegible] Seoul directly. Effects on downstream users [illegible], were thought to be large and would [illegible] ibly through increased costs of [illegible]

For Se[illegible] ronmental problems associated with [illegible] pollution from fuel combustion [illegible] of the industrial working environm[illegible] air pollution loadings have been est[illegible] all fuels, including gasoline and diesel fuels used [illegible] vehicles (Table 18), the separation of mobile and stationary sources and the relationship of these to ambient air quality could not be confidently done. However, high SO_2 concentrations in the air in both industrial and commercial sections undoubtedly relate to the use of Bunker-C oil for heating and power plants.

Permissible industrial stack-emission concentrations were excessive in the opinion of the Smithsonian consultants. Exposure of workers to high concentrations of various pollutants in the factory or workshop was perhaps the most serious aspect of industrial pollution. Small workshops

used the *ondol*, with the possibility of CO poisoning; the problem had been documented. Anthracite briquet factories were extremely dusty inside and were an obvious health hazard. In other plants, leakage of gaseous pollutants to the interior was reported to be common.

A second, equally serious aspect of the industrial working environment pertained to accidents. However, good accident data were not available. Although accidents were the leading cause of death in Seoul, deaths in industrial occupation were not segregated from total accidental deaths. They were estimated to represent 50 percent of the total, however. No information existed on illness originating from industrial occupations or industrial pollution.

It was strongly recommended that industries be made to improve their working environments and practice safety procedures. New industries should be required to use the best available and feasible pollution-control technology. Following the 1973 emissions inventory, surprise spot checks on emissions were suggested as a technique to aid enforcement of emissions limits.

4. *Transportation and Its Impacts*

The automobile has proved to be the main polluter in any ground transportation system. It requires inordinate amounts of space. The combustion of gasoline generates many air contaminants. High accident rates per passenger kilometer are typical, and automobiles are noisy. Seoul had only 67,000 automobiles in 1972, but the number was growing fast, and the trip-making rate of existing autos made them equivalent to approximately 10 times their number. Although buses absorbed two-thirds of all passenger trips per day (or about 5.0 million passenger trips), over 550,000 car-generated trips in central Seoul were made daily. That is, automobiles dominated traffic patterns and physical volume of vehicles, if not passenger trips.

The rate of automobile ownership was increasing rapidly--a fourfold increase in numbers during 1965-1972--and automobiles were rapidly creating serious congestion in central Seoul. This has been remedied to some extent by new streets and widening of streets. However, these improvements have reached their limits. Congestion and high volumes of pedestrian traffic have resulted in high accident rates, which is not surprising, although, with better pedestrian/vehicle segregation and other safety measures, deaths and injuries have declined in relative terms if not in absolute terms: in Seoul, 565 traffic deaths were recorded in 1969, 725 in 1971, 748 in 1972. Total traffic accidents in 1972 were 20,186, down somewhat from 21,610 in 1971.

Automobiles, as well as buses, pollute heavily in Seoul, especially inside the five-kilometer ring. Gasoline combustion was estimated to generate 57 percent of the total CO loading in Seoul's atmosphere and 41 percent of total hydrocarbons. Diesel combustion contributed another 34 percent to total hydrocarbons and 15 percent of the total dustfall.

Temperature inversions and clear skies in the autumn and winter exacerbate air pollution, but adequate meteorological data for predicting episodes and interpreting air pollution did not yet exist.

Increasing concentrations of all major air pollutants produced by gasoline engines had been found in various air-quality surveys undertaken since 1965. Nitrogen had risen to dangerously high levels by 1969 even in residential areas. Sulfur dioxide and dustfall had both been increasing since 1969 in all zones of the city, including parks and gardens. Spot checks of CO concentrations showed levels ranging from average values of 33 ppm to highs of 100 ppm in the central district. These various concentrations are high--excessive by standards in the U.S.A.--but the human health impacts are not readily interpreted, partly because of lack of data and partly from lack of knowledge as to the long-term consequences of sublethal poisoning by various air pollutants.

In contrast to increasing air pollution from automobile sources, noise pollution (noted by Smithsonian consultants in 1972) stemming from the undisciplined use of horns had been controlled. It was illegal in 1973 to use horns in the central business district.

The construction of a subway and of ring and radial roads was planned to remedy the problems of congestion as well as absorb the increasing volume of CBD-oriented trips. The subway will enable the dispersion of resident population from the city's core area to low-density, outlying areas. Five lines will be built; the first, to be completed in 1974, will carry as many passengers per day as all automobile trips per day in 1972. The entire system is to be completed by 1985. Construction began in 1971, at the early stage of automobile-traffic and air-pollution problems and before the automobile had totally dominated the transportation system. If automobiles eventually are prohibited from the core city area--a possibility city planners have mentioned--then local air pollution and congestion will be greatly alleviated, at least in downtown Seoul.

The subway is a forward-looking response to the exploding transportation demands, and the decision to build it illustrates the uses of a long-term planning horizon that should be employed in other solutions to impending and predictable urbanization problems. The subway plan approaches in a realistic manner the trend in trip-making and vehicular flow. This was not true in the planning projections used for the city's water supply, in which both population growth and trends in the pollution of the Han River were greatly underestimated.

5. *Squatter Settlements*

During the 1950's and 1960's when Seoul's population was exploding from 1.5 million to 5.0 million, many of the new arrivals apparently formed squatter settlements. In 1973 an estimated 165,000 squatter dwellings in Seoul housed

approximately 1.5 million persons, as many as 50 percent of whom were tenants. Of these dwellings, 120,000 were illegal or lacked land title and were subject to elimination. The settlements were largely on public land, forming sizable communities on river-edge locations or in the rocky hills in the city. Only 30 percent were scattered singly or in small clusters. Houses in hillside settlements were in better condition than riverine settlements. Water supply was a problem in all squatter settlements.

In recent years the flow of in-migrants had diminished for a number of reasons: prohibitions on new squatter housing backed by strict enforcement, rising prices, fewer jobs, crowded living conditions, and improving conditions in the countryside. If these disincentives continue, in coming years the city will not have to cope, after the fact, with new settlements and housing.

Various methods of removing existing squatter communities had been tried. Low-cost "citizens" apartments were constructed, some on land formerly occupied by squatter shacks. Four hundred and fifty of these buildings were constructed. Squatters were given preference in purchase of the dwelling units, which have deteriorated rapidly. Many relocated squatters could not afford rent and interior completion costs, and they moved out. Experience of other countries has been similar. The satellite city Kwang Ju was conceived and constructed for the similar purpose of relocating squatters whose settlements in Seoul were razed. Initially it did provide housing for squatter households relocated from Seoul to Kwang Ju. But between 1969 (the first year of the settlement) and 1973 many former squatters returned to Seoul. In 1973, 28,000 of the original squatter relocatees still lived in Kwang Ju, whose total population was 140,000. Kwang Ju is now under the jurisdiction of Kyongii Province rather than the Special City of Seoul, and it has been renamed Sungnam City.

In 1973, the policy on squatter settlements, implemented by the new Bureau of Housing in the City Government, combined strict enforcement of prohibitions on new illegal settlements with the enforcement of a series of housing codes and regulations. The gradual implementation of these codes will steadily eliminate at least 120,000 illegal units as well as others that do not meet certain criteria. The housing codes require house and lot sizes that are more characteristic of middle- and upper-class settlements, with the effect that they discriminate against squatter lot size and house construction. While squatter builder/owners may be given certain incentives to relocate, the impact of the codes on the numerous tenants--who may comprise as much as 50 percent of the total squatter population--had not been considered.

The contribution that squatters make to the city as manual laborers, artisans, skilled workers, budding entrepreneurs, and trash or night-soil collectors must be weighed against their liabilities to the city, such as the blight of slum settlements. This liability could of course

be corrected, and squatters generally could improve their homes when they have the resources. The city could lend help, as has been done elsewhere in the world, especially in Latin American cities. The provision of adequate infrastructure and services (water, sewers, schools, fire prevention, etc.) is more of a problem and clearly is the city's responsibility. The justification of the needed investment must take into account the positive contributions that the low-income slum dwellers make to the city.

Squatters and slums probably should be considered an inevitable adjunct or rapidly growing cities. They are the only solution to the inability of a city to provide low-income housing. To accept their inevitability and potential positive contribution to a city's life would mean that space for squatter settlements should be anticipated in future physical plans for fast-growing cities. In Seoul, space for squatters was not anticipated, and public space needed for parks and right-of-way had been usurped by squatters. To the extent that the best use of this space is as planned rather than as squatter settlements (even improved ones), certain settlements eventually will have to move. Hopefully, in those cases where cohesive, improved communities were developing, it will be possible to accommodate public space requirements without destroying the communities.

Research and surveys are needed to define better the role of the squatter and the dynamics of squatter settlements and in order to provide a better basis for policy in Seoul as well as other Korean cities. Relaxation of certain criteria used in ruling on the eligibility of existing squatter housing for upgrading and the standards for upgrading were recommended.

C. DEFICIENCIES IN ENVIRONMENTAL BASELINE DATA

In 1973, neither the existing condition of Seoul's environment nor trends in environmental quality were possible to determine with satisfactory accuracy because of the serious lack of baseline data for ambient air quality, water quality, human health, industry, and demographic movements. The various environmental problems and their impacts had to be described largely on the basis of publications of occasional research and survey work, interviews, and personal observations. Cause-and-effect relationships between environmental pollution and human health impacts could not be confidently determined.

Although both air and water pollution were being systematically monitored in 1973, and a good start had been made in obtaining baseline data, some problems still remained as of late 1973. The best analytical techniques, in terms of accuracy as well as feasibility, had not yet been worked out for several air pollutants. Results of tests from different instruments and/or methods differed widely in some cases. Selection and adoption of standardized instruments and methods for the monitoring network therefore

remained to be done.* Twenty-five air-sampling stations were in operation, or an average of one location per 24 km^2. However, only SO_2 and dustfall were being systematically analyzed. Other pollutants were only occasionally monitored, either by the city's Bureau of Environment or the National Institute of Health, which operates a mobile air quality laboratory. There was a lack of good meteorological information for interpreting and understanding the significance of pollutants measured at sampling points. No good progress has been made in this direction.

Water quality of the Han River began to be systematically monitored only as of 1969. Data from earlier surveys were not readily comparable; hence, trends were difficult to establish. Monitoring data were not yet related to streamflow, and interpretations of sample results were made difficult. No emissions inventory yet existed for the 4,300 industries registered in Seoul in 1972; thus, potential pollution-loading from these sources could not be estimated. However, a Rapid Survey undertaken in late 1973 will have helped correct this deficiency.

Health statistics for Seoul's population, especially incidence of disease, were virtually nonexistent, at least in terms of the quality of data needed to draw relationships between environmental conditions and public health. Reported cases of diseases and deaths did, however, suggest the general situation and trends.

These deficiencies or gaps in data must be corrected in order to characterize accurately the quality of Seoul's environment, to establish criteria and standards for environmental quality, to assess the effects of pollution control efforts, and to establish a basis for assessing the costs of pollution.

D. INSTITUTIONAL RESPONSE

Legal, organizational, administrative, and other actions had been taken to meet the environmental challenge, especially since 1972. The results were beginning to be seen in 1973. The legal background for environmental pollution control in Seoul is a Public Nuisance Control Law of November 1963 which was revised and passed in amended form in January 1972. The law establishes, among other things, limits to industrial emissions at the source and at the plant boundary. Permissible levels are high by U.S. standards. Effectiveness of the law cannot be evaluated without the results of an emissions inventory, which in itself would be a major factor in enforcement. Cha (1973) has evaluated the content and implementation of this law.

The Public Nuisance Control Law was designed mainly to control air, water, and noise pollution by means of enforcement of emission standards, whose establishment is the

*Standardization and uniformization in monitoring are not problems exclusive of developing countries (CEQ, 1973).

responsibility of the Minister of Health and Social Affairs. Cha (1973) notes that the initiative for the law was a proposal made in 1962 by leading businessmen in the private sector who anticipated the environmental pollution problem inherent in Korea's ambitious industrialization goals. These well-informed entrepreneurs had observed the increasing pollution problems in Japan and envisioned the inevitability of pollution-control needs and the consequent business opportunity for control technologies. Government leaders also recognized the imminent advent of pollution in relation to industrialization, and the proposal became a law in 1963.

Increasing numbers of complaints of pollution damage throughout the nation compelled the government to begin enforcement of the law in 1967, at the end of the first five-year plan. Continuing pollution complaints together with increasing awareness and publicity of environmental pollution worldwide in the late 1960's led to a revision of the law which added a construction permit system and the requirement for environmental impact studies related to public development projects and plans. The implementation of these two revisions was not reviewed and evaluated by the Smithsonian survey team. But Cha (1973) notes that there are no provisions in the law which describe how the environmental impact requirement should be met. He cites other problems in its implementation: poor farmers and fishermen do not have the capability of producing the kind of evidence of pollution damage that is requisite to the arbitration procedure provided for in the law; the budget of the Ministry of Health and Social Affairs has been declining; and sufficient numbers of trained personnel and adequate equipment are lacking.

"The level of fiscal support has never been sufficient; the level of competence of enforcement personnel is appallingly low, leaving much to be desired in terms of need for massive improvement in professional training, as well as technical know-how" (Cha, 1973, page 115). While Cha considers the law to have failed its purpose, the basic reason is, in his opinion, "the fact that economic development as the national goal in Korea has been so pervasive that everything else has been subordinated to its accomplishment" (Cha, page 116).

The city government of Seoul has created a Bureau of Environment whose functions include collection and disposal of solid and human wastes, monitoring of water and air quality, and administration and control of environmental standards and regulations, especially those affecting industries and public health. This is a considerable improvement over previous organizational efforts.

At the national level, an Environmental Data Center has been set up within the Korean Atomic Energy Research Institute, located in Seoul. The objective of the Center is to collect all information relevant to environmental pollution, standards, criteria, abatement, and economics--

to mention a few topics--with special regard to guiding future industrial growth in Korea so as to minimize environmental impacts and damages. The scientific and technical background for environmental policy is to be developed.

Considerable research capabilities existed in various universities and research institutes in Seoul, but, with some exceptions, these had not yet been engaged in helping define, measure, or solve Seoul's environmental problems. This was a serious failing since the city was losing by not tapping these intellectual resources, and the academic institutions were losing by not being in contact with the "real world" problems of the city. Furthermore, the Seoul City Government will be a future job market for university graduates, the nature of which must be anticipated by the city and the universities in order to provide for the needed training programs. For instance, the Zimmerman wet-oxidation plants require highly trained engineers and technicians for their operation and maintenance. A system of such plants will therefore require a sizable corps of specialists whose training must be planned in accordance with the scheme's plant installation timetable.

While the Seoul City Government had better organized its efforts to monitor and administer the urban environment, an administrative mechanism for developing environmental quality goals had not yet evolved. Major decisions made on urban infrastructure, zoning, and land use were affecting and had affected environmental quality. To the extent that Seoul will achieve a decline in growth rate and a consolidation of gains in economic growth, specific quality goals for the urban environment should now be included in all major planning and administrative decisions affecting the city. It was recommended that an environmental policy be drafted for Metropolitan Seoul that would guide short-term development and long-term management decisions.

E. LESSONS FROM SEOUL'S EXPERIENCE

The case study did not include a review and evaluation over time of major decisions and policies affecting the urban environment made during Seoul's period of rapid growth. Such an evaluation is the necessary counterpart of an environmental assessment of the type done in order to establish the relationship between policy, planning, and administration and the ultimate consequences of each on an urban environment. This was beyond the scope of the case study for it would have entailed a distinct study effort with different disciplines represented. However, a number of lessons can be drawn from the accomplished survey.

1. *Growth Rates*

Projections of the city's growth rate were low in the early 1960's, at least as evidenced by assumptions made to

compute the future demand for water. By 1966 the city had already surpassed the 3.8 million mark that water planners in 1963 had forecast for 1973. The reason for the underestimation is not clear since growth rates in the 1940's and 1950's had been high, not low, with the exception of 1951 and 1952 when Seoul lost population. But from 1953 to 1960 the population more than doubled--from 1.06 million to 2.3 million.

The explanation may be that accurate forecasts were not essential. In 1962 the water system supplied water to only 27 percent of Seoul's population, which in itself was strong justification for expansion and improvement. However, the population projections for estimating water demand may have misled estimates on the increase in water pollution, which in turn has complicated the protection of Seoul's water supply.

Population estimates of 7.5 million by 1981, made in planning Seoul's subway system, are more realistic and anticipate increase in population density outside of the present limits of the city. The construction of the subway system will, of course, help fulfill that projection. One of the best earlier projections was made by the Department of Urban and Regional Planning of Seoul National University (SNU, 1970) in a study undertaken to project future land and floor space requirements in Seoul's central business district. Using a 7.3 percent growth rate, the study accurately projected Seoul's 1973 population of 6.3 million. That study projected 11.0 million for 1981, in contrast to the subway planners' 7.5 million, plus 2.5 million outside the city limits.

Traffic congestion and its economic consequences compelled more realistic estimates of growth rates than did demand for water. The water pollution consequences of rapid population growth certainly constituted a less dramatic problem--at least initally--than did the immediately felt impacts of congested CBD traffic. Furthermore, even today, city officials state that there are no insoluble problems in adequately treating the raw water from the Han River. While pollution of the Han does constitute a potential hazard to public health if it is not controlled in the purification system, it is perceived as more manageable than traffic congestion.

2. *Satellite City*

Kwang Ju was designed to serve an immediate, single-purpose policy of relocating squatters from settlements in Seoul that it had been decided to demolish. However, Kwang Ku's economic viability was not planned nor were the employment needs of the resettled squatters adequately taken into account. Although Kwang Ju was not intended to be integral to the satellite cities scheme, its difficulties did not augur well for such a solution to squatters and in-migrants. That scheme has since been abandoned, although perhaps only temporarily.

It is clear from the Kwang Ju experience that a satellite city's functions and purposes need broader definition if a viable urban community is to be the result. Such a city must become a new urban settlement first and foremost. Municipal sites and services essential to any city should be provided in a timely manner. Special provisions are required if large numbers of unskilled, poor in-migrants are to be attracted, or induced, to migrate to a new city such as Kwang Ju. There were insufficient employment opportunities in that city for these people. In poorer families many members work in order to obtain sufficient income. The chief wage earner of poor families may not be permanently employed, which is typical of construction laborers, for example. Second and third wage earners may take servants' jobs, work as messengers, and so forth. A large city clearly holds more opportunities for such jobs than does a smaller new city, and particularly one in which low-income people predominate. Lacking alternatives, many poorer dwellers will move to the larger cities out of economic necessity, as appears to have been the case in Kwang Ju. And as in other satellite city experiments, they were replaced by people with high incomes.

3. *Water Pollution*

To the extent that pollution of the Han River has not yet caused major epidemics, the relative lack of emphasis on wastewater collection and treatment and the placing of emphasis on extending water supply to the city's population might be seen as a justifiable policy. It is not clear, however, that this was a well-reasoned policy. It seems more likely to be the result of incomplete planning. Its success depends on the maintenance of pressure in the distribution system so that back pressure and contamination from wastewater in the subsoil through leaks do not become health hazards. Also, pressure in the system is essential for fire fighting. The city has been more successful in extending the system than in maintaining pressure in the system and in preventing leaks, with the consequence of real or potential contamination, loss of water, and inadequate pressure for fire hoses.

It is too early to assess whether it would have been cheaper to install from the outset a water-carriage system for human wastes that would entail mandatory installation of flush toilets in all dwellings. Until Seoul has completed the construction of a sanitary collector sewer network, the costs of such construction after, rather than before, high-density buildup cannot be known. Also, until the impact on downstream water resources of Han River pollution is monitored and assessed, this externality is an unknown. However, the resource value of receiving waters obviously should be a major factor for any growing city in the formulation of a domestic waste-treatment policy.

A policy of constructing sewers prior to housing construction would, of course, have precluded squatter settlements and other illegal housing if it were to be effective. Prior to housing construction the provision of a water supply and sanitary collector sewer system would have been essential. This in turn would have required an explicit housing policy, which Seoul did not have. In short, a planned approach to urban land development and housing for all income levels would have been needed. In essence, Seoul's policy of converting from a system of cesspools/fermentation basins to cesspools/combustion, and ultimately to septic tanks or toilets with a sanitary collector sewer system feeding into sewerage treatment plants, can be seen as the inevitable outcome of short planning horizons, lack of comprehensive planning, and neglect of the environmental and public health impacts of wastewater problems--all of which, of course, may reflect scarce human and financial resources rather than lack of awareness. In any case, it is clear that adequate policies, staff, and financial support are crucial to the interrelated problems of housing, water supply, and wastewater.

4. *Human Wastes*

Until feasible new technologies are developed for collecting, treating, and disposing of human and other organic wastes, other large Asian cities with the same problem might view the wet-oxidation combustion system as an interim solution for unmanageable volumes of human wastes. However, the technical and economic aspects of combustion must be weighed against the inevitable need for a water-carriage sewerage system which handles all waterborne wastes. For a newly growing city, the early planning for a water-carriage system for human and other wastes and the scheduling of the necessary investments are clearly preferable to postponement and subsequent reliance on single-purpose solutions such as the combustion method. For a very large city, composting of all organic wastes is not a viable proposition because of health hazards, notwithstanding the values of compost for soil-fertility maintenance. However, a portion of organic wastes could be composted, provided that sanitary handling and treatment is accomplished. Composting should be subsumed under the more important public health criteria for organic-waste collection and treatment. The composting option is also influenced greatly by the particular characteristics of a city and its surrounding region, including the nature, presence, and extent of farming activities, the man/land ratio, transportation systems, and so forth.

5. *Solid Waste*

The observed efficiency of solid-waste collection and recycling in Seoul is in large part a consequence of the existence of large numbers of collectors, scavengers, or

buyers who find value in wastes. As per capita income rises, this situation will undoubtedly change. Conversion to capital-intensive rather than labor-intensive waste salvage might eventually be required, although the probability is difficult to envision in the near future. Timing of the conversion will require projections of the comparative economics of labor-intensive versus capital-intensive systems and necessarily will be based in part on employment and income forecasts as these relate to the lowest income groups.

6. *Squatters*

The lessons to be extracted from Seoul's experience with squatters are several, although subject to qualification because of the paucity of demographic and socioeconomic information on this portion of the city's population. In fact, it could be argued that the most important lesson is that the City of Seoul's approaches to the squatter settlement question have been greatly hampered by the lack of good information on this segment of the urban population. Why the right questions were not asked in a timely way is not clear. Current policies towards squatters indicate that the city views them as social problems to be dealt with through control of physical settlement rather than as potentially important human resources. Efficiency objectives apparently have been and continue to be more important for Seoul than equity objectives.

The growth of squatter settlements is inevitable unless population movement in general is controlled by police action. The experience of large cities everywhere in developing countries bears this out. Even low-income housing is not liable to prevent these settlements. To date, such projects have tended to serve persons higher on the income ladder, not the lowest income earners who resort to squatter construction. Also, illegal settlement of unused land, perhaps scheduled for other purposes, is inevitable if no controls exist.

To the extent that squatters make a successful entry into city life by gaining employment and investing money to improve their housing, they become an economic force--and a political force, whether it is expressed or not. However, in the absence of socioeconomic and demographic data concerning the mobility, intracity migration, and employment of squatters, their contribution to city life and their economic and political importance can only be conjectured, and the basis for good policy is weak. If one accepts the proposition that squatter settlements house people who make a positive contribution to city life, then a policy for improving their housing and the extending of municipal services to their settlements is a desirable one. This goal, moreover, is justified by the fact that human and other wastes generated by this segment of the population not only pollute their immediate living environment but contribute to general ambient pollution. Above all, it

seems clear that a certain level of support and land-use planning should be undertaken in anticipation of the inevitability of an influx of low-income migrants--which is to say, the major proportion of migrant populations who account for rapid urban growth.

7. *Environmental and Related Socioeconomic Baseline Data*

An important, perhaps the most important, lesson centers around the relative lack of good baseline data on the city's environment. It is clear from the Seoul case study that earlier systematic water-quality monitoring of the Han River and its tributaries draining the city would have greatly helped the planning and protection of the city's water supply. An earlier comprehensive appraisal of water-pollution potentials based upon better population estimates and upon public health impacts of water pollution might have resulted in different decisions or timing of policy concerning the collection and treatment of the city's wastewaters and of human wastes. Also, it is clear that the lack of morbidity data for the city's population prevents adequate analyses of the public-health impacts of known pollution.

Data deficiencies are not atypical of developing countries, which, in addition to lacking environmental baseline data, are chronically deficient in all kinds of data needed for planning and forecasting. While Korea's outstanding success in achieving economic development goals indicates that the status of socioeconomic data has not yet been a limiting factor in development planning, it is clear that there is insufficient baseline data for environmental planning and management.

Environmental problems emerged with the physical and economic growth of Seoul, with steadily more serious impacts. The straightforward conclusion can be made that rapid growth demands continuous monitoring of environmental pollution, other environmental impacts such as congestion, public health indicators of pollution, and socioeconomic measures of all environmental impacts. Even if policies and management programs for environmental quality are postponed until some future date, these must necessarily be founded on a good data base indicative of environmental trends and impacts.

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