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# The Urban Environment of Seoul, Korea

## A Case Study of the Impact of Rapid Urbanization

Editor
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## Preface

Urbanization is synonymous with industrialization and the environmental problems of modern industrial society are nowhere experienced as acutely as in the large city, both in developed and developing countries. Cities in developed societies are coping with problems of air, water and noise pollution, and congestion with varying degrees of success. But these problems have emerged at a more gradual rate than is the case in developing countries, where urban growth is accelerating at rates unprecedented in human history. Doubling times are ten years or less in the larger cities and their rates are predicted to continue. The speed with which environmental problems and their impacts are being experienced in developing country cities is virtually unknown in more developed societies.

How can the urban environment be managed in a situation of rapid growth? What are the critical problems that can be anticipated? There is clearly a need for an examination of these problems in order to develop a basis for policies and plans appropriate to the unique circumstances of developing countries. With this in mind, the U.S. Agency for International Development contracted the Smithsonian Institution's Office of International and Environmental Programs to undertake a case study of Seoul's urban environment. The case study is one of a series that examined development situations that have generated adverse environmental impacts, in order to provide the basis for formulating adequate environmental policies and help orient development so as to better take into consideration the environmental consequences.

Preliminary visits were made to Seoul in 1971 by Mr. William L. Eilers, Smithsonian Institution, and Dr. Athelstan Spilhaus, Woodrow Wilson International Center for Scholars. Arrangements were made with the City of Seoul to carry out the case study, and the principal areas and disciplines of study were identified. Following these visits, nine scientists of particular competence in their fields visited Seoul for periods of three to six weeks in 1971 and 1972, and wrote reports on transportation, squatters and in-migrants, the Kwang Ju satellite city, water and air pollution, solid wastes, urban insect and rodent pests, and public health.

A workshop held in Washington, D. C., in 1972 in which all the contributing scientists participated, served to define the major issues and integrate the various reports. A comprehensive document containing summaries of the technical reports and the workshop proceedings was further discussed, updated, and modified at a workshop in Seoul in 1973. City and national governmental officials as well as university academicians participated, and three of the contributing U. S. scientists took part also.

The present report on Seoul's urban environment incorporates the results of the two workshops and written commentary submitted by the City of Seoul. It was prepared and edited by Peter H. Freeman, Project Manager, International Environmental Assessment Studies Program, Office of International and Environmental Programs. Mr. William E. Eilers, Deputy Director of the Office of International and Environmental Programs, was co-editor. Participating U.S. scientists (see Acknowledgements) contributed substantive editorial commentary to Part I of the case study.

Part I summarizes the principal environmental problems and evaluates Seoul's experience in terms of its significance to other rapidly growing cities. Part II presents the full report and is organized by the specific topics studied by the U.S. scientists.

Acknowledgements

The Smithsonian Institution gratefully acknowledges the invaluable cooperation and support of Mayor Yang Taek-Shik, and Second Vice Mayor Kim Eung Jung, and his predecessor Mr. Choi Jong Wan, of the City of Seoul. Their willingness to have foreign scientists examine Seoul's critical environmental problems is a remarkable demonstration of international cooperation and of perception of the value of outside points of view. Sincere thanks are extended to the city officials and technicians who readily provided time and information. A special debt of gratitude is owed to Mr. Lee Choong Woo, Chief of the Office of Municipal Administration and Development, who was instrumental in preparing and carrying out the 1973 workshop that was so crucial to the success of the case study.

The USAID mission in Seoul extended invaluable cooperation and support throughout the study. The continuous help of Dr. Newman Hall, Science Advisor, is particularly acknowledged. Mr. James K. Thomas, USAID Engineering Officer, made an excellent contribution to the 1973 workshop.

The Smithsonian Institution is deeply grateful to the participating United States scientists who contributed their time and expertise without fee. Their work exemplified the academic

excellence and international cooperation in research which is the basis for sharing knowledge among nations. Their names and the titles of their technical reports are listed below:

| | |
|---|---|
| Dr. Kyle R. Barbehenn (rodent pests)<br>Visiting Fellow<br>Center for the Biology of Natural Systems<br>Washington University<br>St. Louis, Missouri 63130 | "The impact of urbanization on pest situations in Korea, 1972" |
| Dr. Frank R. Bowerman (solid waste)<br>Chairman<br>Department of Civil Engineering<br>Director<br>Environmental Engineering Program<br>University of Southern California<br>University Park<br>Los Angeles, California 90007 | "Observations on the environment of Seoul, Korea; Aug. - Sept., 1971" |
| Dr. Richard J. Coughlin (Kwang Ju)<br>Professor of Sociology<br>New Asia College<br>The Chinese University of Hong Kong<br>Shatin, New Territories<br>Hong Kong | "Urbanization of Seoul: report on a trip to South Korea, for the Smithsonian Institution" |
| William A. Hall, M.D. (public health)<br>Professor<br>Wesleyan University<br>Middletown, Connecticut 06457 | "Human health impacts of urbanization in Seoul, Korea" |
| Dr. James P. Lodge (air pollution)<br>Laboratory of Atmospheric Science<br>National Center for Atmospheric Research<br>Boulder, Colorado 80302 | "Air pollution in Seoul" |
| Dr. Perry L. McCarty (water pollution)<br>Professor of Environmental Engineering<br>Department of Civil Engineering<br>Stanford University<br>Stanford, California 94305 | "The effect of rapid urbanization on water supply and pollution: a case study of Seoul, Korea" |

| | |
|---|---|
| Dr. Harold D. Newson (insect pests)<br>Associate Professor of Entomology<br>Pesticide Research Center<br>Michigan State University<br>East Lansing, Michigan 48823 | "Urbanization in Seoul, Korea: entomological considerations" |
| Dr. Joan Marie Nelson (squatters)<br>Institute Associate<br>Urban Institute<br>2100 M St. N.W.<br>Washington, D.C. 20037 | "Migration, integration of migrants, and the problem of squatter settlements in Seoul, Korea" |
| Dr. Joseph L. Schofer (transportation)<br>Associate Professor<br>Department of Civil Engineering<br>Northwestern University<br>Evanston, Illinois 60201 | "Perspectives on present and future relationships between transportation and the environment in the City of Seoul, Republic of Korea" |

All the U.S. participants were highly impressed by the dedication, motivation and competency of the Korean technicians and scientists whom they visited in the City Government and in the various ministries, research institutions, and universities. On their behalf, the Smithsonian Institution expresses sincere thanks for the attention and friendly cooperation which they were accorded. A partial list of the persons interviewed appears in Appendix A.

The invaluable help rendered by Dr. Charles A. Frankenhoff, Jr., Graduate Department of Economics, University of Puerto Rico, is gratefully acknowledged. He led the first workshop, drafted the proceedings, and lent a comprehensive perspective to the case study that was critically needed.

Finally, grateful acknowledgement is extended to the Korean participants of the August, 1973, workshop in Seoul, Korea. They readily engaged in frank discussions and critique of the Smithsonian case study. Their indulgence to the necessarily imperfect perspective of foreign scientists was indeed generous. The names of the participants appear in Appendix B.

Special thanks are given to persons who typed various versions of the case study. Helen D. Davidson prepared the original review document. Joanne Witt typed the present, final version.

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# Part I

## Summary and Evaluation

This part is an integrated summary of the survey of Seoul's urban environment. It contains the thoughts and materials developed from the two workshops held during the course of the study. Also, in the last portion, lessons that emerge from the case study are set forth. The summary focuses on what were considered to be the principal environmental problems, and omits mention of several human health and pest problems which, although important, were not considered to be of the same magnitude as those summarized. All the topics studied are presented in Part II.

## A. PRINCIPAL ENVIRONMENTAL PROBLEMS IN SEOUL: A SUMMARY

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 <u>ondol</u> 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 is 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 from slow-burning briquets are conducted through a system of flues that run almost horizontally under the floors of elevated sleeping chambers, and thence vertically through one or more chimneys. In the country wood and charcoal are burned, but in Seoul large circular anthracite briquets with holes for draft, manufactured in some twenty factories, are employed.

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, resulting in better air ventilation, 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 the 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 or illness from sublethal CO poisoning can result; the incidence of illness in Seoul is not known.

Another impact is the enhanced probability of tuberculosis transmission. A frequent air turnover would work against the efficiency of the ondol heating system. The relatively warm, stagnant 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 in Seoul. Further, the ash produced in burning the briquets results in a very considerable disposal problem. Of an average of 7,000 tons per day of solid waste collected in Seoul during 1973 which must be disposed of in landfills, roughly 60 percent consists of briquet ashes. The making, handling and burning of anthracite briquets also generates almost 30,000 metric tons of dust per year (Table 18).

Despite a generous prize offered by the city for several years to find an alternative home heating technology, the ondol system continues to be used. The city has no special program to deal with the various facets of the ondol system. Modern Seoul apartments do not install this heating system, but conversion to other heating and cooking systems, as a result of new housing replacing old dwellings, would take several generations.

The very urgent 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.

## 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 12.

Human excreta was periodically collected from residential holding tanks by laborers with buckets who discharge these into trucks, or by trucks with vacuum pumps and hoses. The latter method decreases accidental spillage during transfer. Besides spillage during transfer, pollution occurred at the disposal sites, 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. Ground water 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 ruled out its recreational value, and perhaps more seriously, it generated special treatment problems for the city's water supply which is pumped from the Han at five intakes and run through treatment plants. The cost of the Han River pollution was high both in terms of lost recreational opportunities as well as 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 intakes 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 (fecal 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 Han River water quality were not made until the start of 1972, so water quality baseline data 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 were eventually to be serviced this way. 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. These plants will have a 3.6 million liter/day capacity and will gradually 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 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 River, flow from the latter being 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 streams draining the city) has been gradually converted into a sewer. One of its tributaries 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 efforts, the Han seemed destined to receive heavy loads of pollutants until all the city's waste waters 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 as well as 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 emission monitoring program, although a Rapid Survey emissions inventory undertaken in late 1973 will have helped correct this deficiency. In 1972 there were a total of 4,300 registered industries and enterprises in Seoul subject to emissions controls as set forth in the 1971 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 Yang River, industrial water pollution does not affect Seoul directly. Effects on downstream users, especially in Inchon, were thought to be large and would ultimately be felt, possibly through increased water treatment costs.

For Seoul, the two major environmental problems associated with industry were ambient air pollution from fuel combustion and the poor conditions of the industrial working environment. Because ambient air pollution loadings have been estimated for all fuels, including gasoline and diesel fuels used in 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 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 occupations were not segregated from total accidental death. 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 precautions. 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 have rapidly created 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 carbon monoxide 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 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 oxide had risen to dangerously high levels by 1969 even in residential areas. Sulfur oxide 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. However, measurements during September, 1973 to May 1974 did not show concentrations in excess of 10 ppm in the central city. These various concentrations are high--excessive by standards in the USA--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 (CBD).

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 out-lying 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 are eventually 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 use of a long-term planning horizon that should be employed in other solutions to impending and predictable environmental 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 6.0 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. One hundred and twenty thousand of these units were illegal or lacked land title, and were therefore subject to elimination. The settlements were largely on public land, forming sizable communities on river edge locations or on 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, however.

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 therefore moved out. Experience in 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 had returned to Seoul. Twenty-eight thousand of the original squatter relocatees still lived in Kwang Ju (now renamed Sungnam City) whose total population was 140,000 in 1973. It is now under the jurisdiction of Kyongii Province, rather than the Special City of Seoul.

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 new 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 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 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 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 should probably be considered an inevitable adjunct of 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 in future physical plans for fast-growing cities, space for squatter settlements should be anticipated. In Seoul, space for squatters was not anticipated, and public space needed for parks and rights-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 will eventually have to move. Hopefully, in those cases where cohesive improved communities were developing, it will be possible to accomodate public space requirements without destroying the communities.

Research and surveys are needed to better define the role of the squatter and the dynamics of squatter settlements, 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 up-grading and the standards for up-grading were recommended.

## B. 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 by 1972 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 sulfur dioxide and dustfall were being systematically analyzed. Other pollutants were only occasionally monitored, either by the City's Bureau of Environment

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*Standardization and uniformization in monitoring are not problems exclusive of developing countries. In the U.S.A. this remains to be done in air quality monitoring (CEQ, 1973).

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 1965. 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 existed yet 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 to be undertaken in late 1973 will have helped correct this deficiency.

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

These deficiencies or gaps in data must be corrected in order to accurately characterize 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.

## C. 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. It was designed mainly to control air, water and noise pollution by means of enforcement of emission standards, whose establishment is the responsibility of the Ministry of Health and Social Affairs. Cha notes that the initiative for the law was a proposal made in 1962 by leading businessmen, 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 60's led to a revision of the law with addition of 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 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; 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, 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 of Seoul has created a Bureau of Environment, whose functions include collection and disposal of solid and human wastes, water and air quality monitoring, 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 impact and damage. The scientific and technical background for policy on environmental issues is to be developed.

Considerable research capabilities exist in various universities and research institutes in Seoul, but with some exceptions, these have not yet been engaged in helping define, measure, or solve Seoul's environmental problems. This is a serious failing since the city is losing by not tapping these intellectual resources, and the academic institutions are losing by not being in contact with the "real world" problems of the city. The City of Seoul will further 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 timetable for installation of these plants.

While the City of Seoul better organized its efforts to monitor and administer the urban environment, an administrative mechanism for establishing environmental quality goals had not yet evolved. Major decisions made on urban infrastructure, zoning and land use were affecting and had affected environmental quality. As Seoul moves toward the 1980's with a declining population growth rate and a consolidation of gains in economic growth, specific quality goals for the urban environment should be included in all major planning and administrative decisions affecting the city. It was recommended that an environmental policy for the City of Seoul be drafted which will guide both short-term and long-term development planning as well as day-to-day management decisions.

## D. LESSONS FROM SEOUL'S EXPERIENCE

The case study did not include a review and evaluation over time of major decisions and policies concerning 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 survey that was conducted.

### 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, these 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 for they anticipate an 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 (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.

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 initially--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 which it had been decided to demolish. However, Kwang Ju'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 auger 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 higher 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 consequences of real or potential contamination, loss of water and inadequate pressure for fire hoses.

It is too early to assess whether or not it would have been cheaper to install from the outset a water carriage system for human wastes, which 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 build-up 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. 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 may reflect scarce human and financial resources. It is, in any case, clear that adequate policies, staff and financial support are crucial to the inter-related 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 without sewer systems 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 water-borne 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 is clearly preferable to postponement and subsequent reliance on single purpose solutions such as the combustion method. 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, providing sanitary handling and treatment is accomplished. Composting should be subsumed under the more important public health criteria for organic waste collection and treatment.

5. Solid Waste

The relative efficiency of solid waste collection and recycling in Seoul is in large part a consequence of the existence of large numbers of people who are poor enough to find value in wastes, either as collectors, scavengers, or buyers. 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 will necessarily 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 socio-economic information on this portion of the city's population. In fact, the most important lesson is, it could be argued, 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 up 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 socio-economic and demographic data concerning the mobility, intra-city 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 the improvement of their housing and the extension of municipal services to their settlements is a desirable policy. 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 Socio-Economic 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. These data deficiencies are not atypical of developing countries, which in addition to lacking environmental baseline data, are chronically deficient in all types of data needed for planning and forecasting. While Korea's outstanding success in achieving economic development goals indicates that the lack of socio-economic data has not yet been a limiting factor in development planning, there is clearly insufficient baseline data for environmental planning and management.

The importance of environmental baseline data for setting urban environmental quality goals, even if these are to be temporarily subordinated to economic development imperatives, has not been clearly demonstrated in the context of developing country cities. Ample demonstration is provided by Tokyo and other large cities in Japan (and other countries) of the steady and incremental 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 judgement for determining the justification, timing, content, and scope of an urban environmental monitoring program in a rapidly growing city.

The effect on humans of highly toxic, poisonous pollutants, such as mercury, lead and certain organo-phosphorous compounds, are well-known. Hence, their control and 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 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, is 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 therefore be based primarily on the establishment of environmental goals whose maintenance or attainment a city considers desirable.

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.

The justification for environmental monitoring and for monitoring relevant demographic and public health indicators, 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 in developing countries, not yet committed to unalterable growth patterns (or compelled by existing patterns) can and should seriously consider these questions.

## Part II

## Report on the Survey of Seoul's Urban Environment

Findings of the survey presented in this report are organized by the subjects studied by the participating American scientists. The original reports of each consultant have been edited to meet the format requirements of this final report and in each instance data has been modified and updated to some extent on the basis of critique and commentary from the City of Seoul and discussions during the workshop in Seoul during August, 1973. The original complete reports of each Smithsonian consultant are on file in the Office of International and Environmental Programs of the Smithsonian Institution and are available to those interested in examining the original data.

# INTRODUCTION

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 the one and one-half year survey of Seoul's environment by the Smithsonian Institution, the city's population increased by over 300,000.

Seoul's estimated population in 1973 of 6.3 million grew at an extraordinarily rapid 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 which proved to be 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 1). The planning projections in 1973 anticipated a leveling off of the growth rate so that by 1981 Seoul would have only 7.5 million. But to this total one should consider another 2.5 million persons who reside outside the city limits but within 45 kilometers of the city's center as being part of the Seoul metropolitan area.

The rapid growth of Seoul is of great economic significance to Korea. Until recently, Seoul has dominated industrial development; in 1966 45 percent of the national production came from

Seoul. 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 1

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 | 4,776,928 | 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 Statistical Yearbook, 1971.
1971 to 1973, City of Seoul estimates.

While there is no single way to assess Seoul's--or any city's--effectiveness, or even of satisfactorily defining effectiveness,* it is possible to inventory the available data, and review the major problems being experienced in the course of rapid growth.

A comprehensive review of Seoul's urban environmental problems, the first of its kind, was undertaken during 1972-1973 by ten social and physical scientists under auspices of the Smithsonian Institution. This multidisciplinary study was carried our for the United States Agency for International Development in order to better understand the environmental impact of rapid urbanization as a basis for formulating urban environmental guidelines for developing nations. 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 the short visits of the U.S. scientists were synthesized in two workshops, in Washington, D.C., and in Seoul.

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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.

The study analyzes the environmental problems that Seoul faced during 1972-1973. A primary concern is to adequately characterize 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 investigated was not made as it was considered outside the scope of this study.

The resulting portrait of Seoul's environment was rough and in places vague, for lack of good information. As better data continue to be developed, better basis for environmental assessment will undoubtedly emerge. But the characterization of Seoul's various environmental problems was sufficiently clear to justify an intensification of the city's efforts to come to grips with these problems. Where problems were only vaguely delineated because of lack of data, there was obvious need for better information. No original field 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, Korean specialists reviewed the draft. Their comments, elicited during a workshop, were incorporated in this final version of the case study.

## A. TRANSPORTATION AND THE ENVIRONMENT*

### 1. Introduction

Transportation systems affect the urban environment directly through air pollution, noise, and congestion, and indirectly through the influence exerted on the density, location, distribution, and movement of people and economic activities. The section describes Seoul's present road network, traffic patterns, and the plans for future transportation, notably the subway plan. Environmental impacts of the transportation system are reviewed and recommendations focusing on transportation planning are presented.

Transportation in a region is both a support system and a unifying force which must be assessed from two perspectives: 1) the degree to which the system meets the needs for moving people and commodities; and 2) the economic, human, and environmental costs of the system. Until recently, transportation systems have been evaluated by economic criteria, but since certain resources and activities which have no market are affected, monetary costs cannot be fully established. Air quality, noise levels, water quality, aesthetics, and valued vistas will be affected by transportation, as will be the spatial disposition and settlement of the city.

Only in the past few years have attempts been made to evaluate

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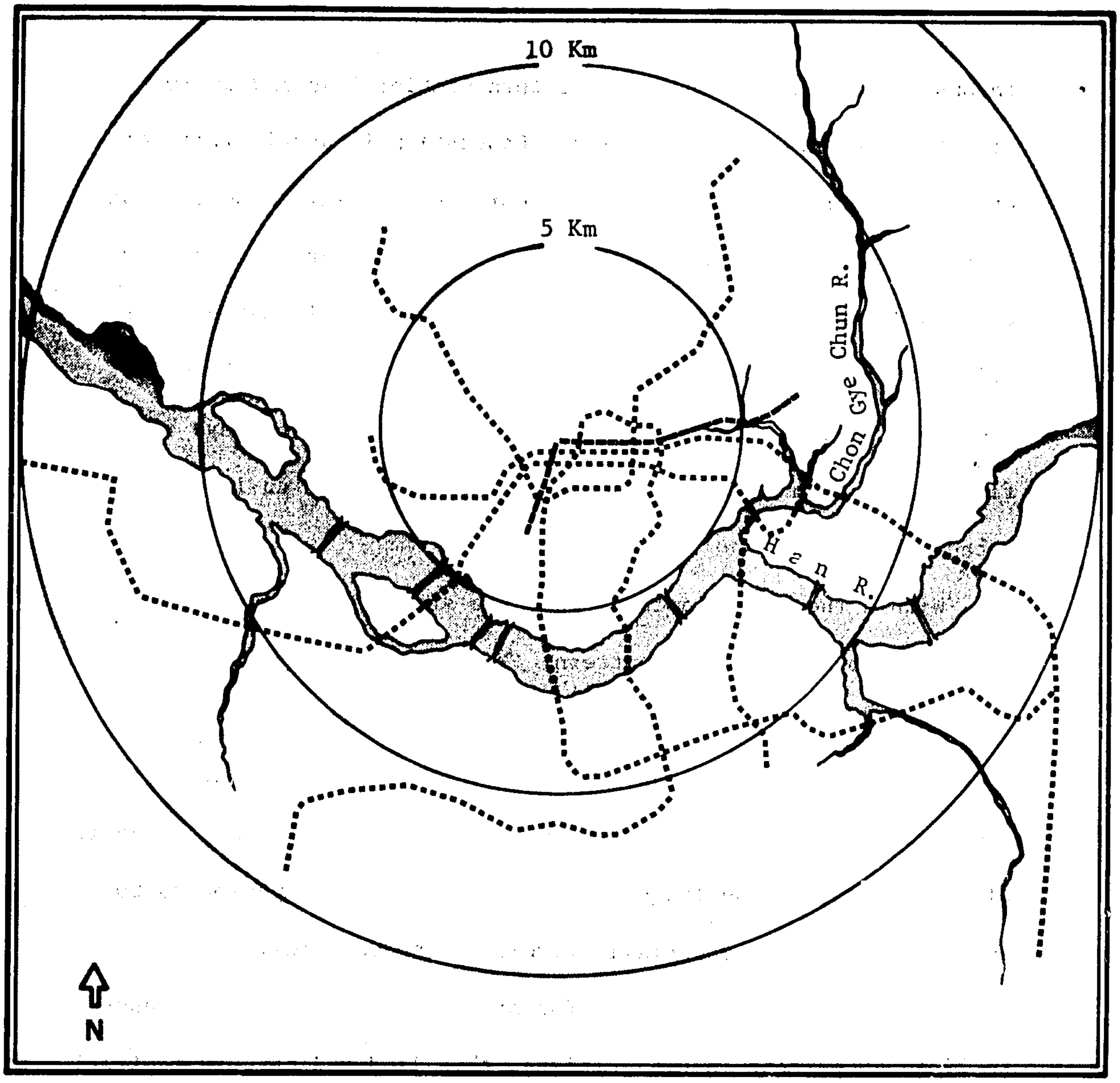
*Originally authored by Dr. Joseph L. Schofer (see Preface).

non-monetary social and environmental impacts. There is no marketplace which establishes the value and costs of those features of the urban environment affected by transportation. Impacts on human health are real but difficult to measure or assign a cost to in terms of public health care. A comprehensive system evaluation is called for, but to date predictive models necessary to support such an evaluation are not reliable. Also, the assumed interactions between transportation and land use are still not well understood. Consequently, the over-all effects of an urban transportation investment on the growth of a city cannot be precisely estimated.

2. The Present Road Network

The transportation system of Seoul is relatively well integrated. Its backbone is the road network, which is being developed and improved to meet current and near-term future needs. A radial network of roads, densest in the northeast to southwest, links Seoul to the hinterlands. Expressways connect Seoul to Inchon and Pusan. Within 10 kilometers of central Seoul, the road pattern is grid-like; major roadways serve as district boundaries, and the downtown grid is dense. However, traffic in central Seoul is extremely congested owing to the absence of viable through routes. This is a consequence of several factors: physical obstacles (Han River, Mt. Nam San, rugged hills around central Seoul),




SPECIAL CITY OF SEOUL

0 5 Km

City limits

Subway routes

planned

under construction

Figure 1. Planned Subway Routes, 1973.

inconvenient combinations of left turn prohibitions and one-way streets, and subway construction. Congestion is partly relieved by a number of short, elevated or depressed highway segments that circumvent intersections and pass over railroad yards. Also, two expressways carry traffic in and out of the central business district (CBD); one--The Samil Expressway--was built on a structure over the Chong Gye Chun Sewage Canal. Existing expressways reflect short term solutions and cannot be considered an integrated urban system.

Within the ten-kilometer ring, the street pattern complements the superblock settlement pattern. Major arterials circumscribe these superblocks. Within the blocks, streets are narrow, sometimes steep, and often impassable to vehicles. This permits high density, short walking trips to jobs and shops, and reduces traffic. Disadvantages include longer trips to the CBD and impediments to emergency services, especially fire-fighting vehicles. While relatively less land is needed for streets (20 percent as opposed to 27 to 30 percent in U.S. cities), this land use pattern restricts the development of an optimum road transportation system.

3. <u>Traffic Patterns</u>

Traffic patterns in Seoul were studied by the Korean Institute of Science and Technology in a 1969 survey which sampled two percent of the city's households (KIST, 1970). More recent comparable data are contained in the city's information publication on the subway plan (Seoul Metropolitan Government, 1973). Data from these two sources are summarized below.

Table 2

Ratio of Traffic Volumes (in %) Related to Means of Transport (1972)

| | |
|---|---|
| Bus | 67.7 |
| Foot | 18.0 |
| Taxi | 8.5 |
| Private Car | 2.4 |
| Other | 3.4 |

In 1969 the trip-making rate of 6.7 million per day for 5.5 million inhabitants was approximately 50 percent of the typical trip-making rate in comparable cities of more developed countries. In 1972, 7.25 million trips per day were made, for an estimated 6.0 million persons.

Buses predominate and contribute greatly to noise and air pollution. But the number of automobiles (especially small and compact types) is increasing fast, from 38,000 to 67,000 in the 1969-70 period. Also, autos are estimated to be equivalent to ten times their number because of high rate of trip-making.

Presently, traffic is extremely congested along the Samil Expressway Corridor, along Sejong Ro and in the southwest corridor. Heavy traffic on 8 to 10 lane streets creates serious flow problems at intersections which, moreover, do not have adequate signals.

Traffic does not circulate between outlying areas, partly because job destinations are in the central city, but also because there are few significant routes to divert non-CBD traffic from the downtown. Moreover, a circumferential route would be most difficult to construct owing to surrounding mountains.

Walking is very important and pedestrian overpasses and underpasses facilitate foot travel in downtown Seoul. The survey found that 29 percent of the personal trips were made on foot; mostly to shop, but also to work. High reliance on foot travel is not surprising, given the low private auto ownership rate (5 per 1,000 persons) and low incomes, and it is apparently encouraged by the superblock settlement pattern. However, within superblocks narrow streets may be used by pedestrian and car alike at the risk of the pedestrian. Drivers and pedestrians are not careful, and accident rates are very high.

No organized statistics were found describing commodity transportation in Seoul. Most of the 21,000 registered trucks are small--1.5 to 2.5 ton capacity--and many are three-wheeled. Within the five kilometer ring, it appears that three-wheeled trucks are employed. These are complemented by human-powered bicycles, handcarts, and A-frame modes of conveyance, which, although forbidden in the CBD in 1973, are still to be seen delivering anthracite briquets and other goods and collecting wastes.

The Central Business District of Seoul is the focal point of the region. Residential areas extend outwards along corridors to the west, southwest, and east primarily, and beyond the five kilometer ring to the northwest. South of the Han River, development is dense to the west, southwest, and east while major industrial development lies along roads to Inchon. Major new development is planned south of the Han River, and a new government center is planned for Yoido Island in the river itself. The current trend reinforces the Central Business District, where land prices have rapidly increased and where zoning has favored commercial and governmental functions, discouraging residential use. Although the Kwang Ju satellite city to the south indicates partial decentralization, the strength of central Seoul as a focal point is increasing.

Transportation needs will be generated by this trend. Presently, 70 percent of all vehicular trips have origins and destinations in the central city. Further concentration of activity there will force increased transportation capacity, which will impact on the most densely developed and most expensive land. Additional air pollution and congestion can be expected.

4. Future Transportation

The subway now under construction will exert a dominant influence on the future transportation in Seoul. Also, three circumferential or ring roads have been planned and construction on one has begun. These could alleviate some of the negative aspects of the present network, but the primacy of the Central Business District compels emphasis on radial service, which is both reinforced as well as provided by the subway.

The subway centers on downtown Seoul and will consist of five lines totaling 75 miles, radiating outward in tunnels to about the ten kilometer limit. One line is already under construction and will open in 1974, but much of the construction will take place after 1977. Running at maximum capacity, the trains will be able to move 84,000 persons per hour in one direction in each corridor. This can be compared to the 10,000 vehicles per hour presently carried on the Sejong Ro at the peak morning traffic. KIST estimates that the line to be opened in 1974 will carry 560,000 persons per day, or 12 percent of total CBD-oriented trips.

The subway is a bold move which, had construction been delayed ten years, may not have been possible. Automobile ownership might have increased with greater prosperity and dominated the transportation system. But now, people are accustomed to public transit and the subway will improve on the existing system. It should discourage acquisition of automobiles, thereby avoiding associated increases in pollution, congestion, and other adverse effects. In fact, it is planned to restrict at some future date the circulation of automobiles in the CBD. However, the subway will rigidify the radial patterns, and will not contribute to circumferential movement. While there may be social, environmental and economic problems associated with this reinforcement of the central city, the advantages of the subway as a transportation mode are clear.

5. Environmental Impacts of Transportation in Seoul

The state-of-the-art of impact assessment of transportation systems is quite limited. In any case, little relevant data were found in Seoul, and few urban transportation professionals had a serious interest in environmental impacts. This is not surprising in view of the necessary focusing of priorities and scarce resources on immediate necessities.

The rapidity of Seoul's growth has, in a general sense, prevented or eclipsed concern for the environmental effects of its transportation system. The impacts are several. Density patterns and the focus of trips on central Seoul tend to increase localized air pollution in that portion of the city. No valid information was available on the contribution of motor vehicles to air pollution, but the proportion has been estimated at 30 percent of the total pollution load (see Table 18).

At street level downtown, the impact is more serious. Congestion in downtown streets, causing idling motors or low speed travel, increases pollutant emissions. Although 80 percent of trips are by predominantly diesel-powered buses and the resultant pollutant loading is thus less than if gasoline-burning engines were more common, engines are commonly underpowered, increasing emissions. On the plus side, absence of private cars obviates "cold start" emissions in the afternoon peak period. The short segments of elevated expressways smooth traffic and help to reduce pollutant emissions. Improvements planned for relieving congestion will have the same effect. The subway will have a favorable effect on air quality or at least not contribute to air pollution, although this was not an objective of its construction.

Vehicles are inspected twice a year under a Ministry of Transport program. The standard for CO emissions is 5.5 percent by volume; particulate production is limited to 2 on the Ringelmann chart. (These parameters are not as accurate as grams per mile over a representative driving cycle now employed by the U.S.) However, the level of enforcement of these standards is uncertain, and, given the lack of accurate long-term air pollution monitoring, it is impossible to judge the impact of this program on air pollution.

Noise from traffic--especially from horns--was a major environmental impact especially obvious to a Westerner in 1971. The unnecessary use of horns has now been forbidden. Little concern has been expressed about noise in relation to subway construction.

Experience in U.S. cities suggests subway noise can be painful, offensive, and hazardous. It is known that excessive noise impairs hearing and interferes with sleep and speech. Prevention of excessive noise needs early attention so as to avoid design decisions that will create irreversible noise impacts. A summary of available noise reduction technology suggested for transit vehicles in the USA is shown on Table 3.

Traffic accidents are a serious impact of transportation. The available statistics, which are good compared to air and noise pollution data, show rates of accidents resulting in injury and death in Seoul are diminishing, but still tend to be high. Rates can be further reduced by better protected pedestrian walkways, more effective separation of vehicles and pedestrians, better traffic signals, improved safety education, stricter enforcement of traffic regulations and laws, and improvements in the expressway system which would permit safer travel at speeds appropriate to length of trip.

The aesthetic impact of transportation systems in Seoul was not found to be of great concern, but ought to be taken into account in the planning of larger-scale, more permanent facilities, such as elevated expressways. On the other hand, displacement of homes and businesses has apparently not been a problem since rights-of-way for new elevated expressways, as well as the subway,

Table 3

Summary of the Noise Reduction Potential by Applying Current Technology to Existing Transit Vehicles

| Existing Condition | Modified Condition | Estimated Noise Reduction dB: Car Interior | Estimated Noise Reduction dB: Car Exterior |
|---|---|---|---|
| Standard track, not regularly maintained | Welded track, ground | 5-15 | 5-15 |
| Concrete trackbed | Ballast trackbed | 0-5 | 0 |
| Bare concrete tunnel surfaces | Strips of absorbent material at wheel height | 5-10 | - |
| Bare concrete station surfaces | Limited absorbent material on wall surfaces and under platform overhang | - | 5-10 |
| Old type vehicles using open windows or vents for ventilation | New type cars with air-conditioning | 10-15 | - |
| Standard doors and body | Improved door seals, body gasket holes plugged, et cetera | 0-5 | - |
| Standard steel wheels | Steel wheels with constrained damping layer | 5-15 | 5-15 |
| Standard type vehicles | Installation of a 4 ft. barrier alongside track | - | 10-15 |
| | Installation of a skirt on side of vehicles | - | 6 |
| Standard, noisy propulsion unit | Modified unit with skewed armature slots, random blower fan blade spacing, acoustically treated fan ducts | 0-5 | 5 |

Source: U.S. Environmental Protection Agency. Transportation noise and noise from equipment powered by internal combustion engines. U.S. GPO. 273 ps. + appendices. 1971 are the natural corridors formed by some very wide arterial streets. This is fortunate in view of the high population densities, and in future land use developments similar rights-of-way should be reserved.

The advantages of the superblock settlement pattern outweigh the disadvantages of limited accessibility, which it is judged can be overcome. Certain streets, for example might be widened to permit emergency access and form firebreaks. A different accessibility problem is posed by the highways along the north bank of the Han River. Their rights-of-way are generally fenced, and they constitute safety barriers to pedestrian access.

A consideration in the incorporation of environmental factors into transportation planning is the nature of Seoul's development. The city may actually by-pass portions of development trajectories followed by other large cities in the world, which could bring it to a size and technological stage far beyond professional and institutional capabilities for dealing with environmental concerns. Monitoring data, forecasting capabilities, and environmental conservation policies will be needed.

Transportation exerts a powerful influence in the shape of urban development and, through this linkage, on the environment. An example is the "sub-civic centers" in Seoul's master plan. These comprise relatively self-sufficient intra-urban growth centers linked to the Central Business District. The seven proposed centers are located on major arterials between five and fifteen kilometers from the CBD and are basically a continuation of current trends. All but two of the centers are already heavily developed. It is not apparent, however, that this spatial pattern will relieve environmental stresses in the central city. More generally, it is not clear whether future transportation plans will support environmentally favorable land use, or even that this interaction is taken into account in planning.

6. Transportation Planning

Presently, responsibility for transportation planning is fragmented, responsibilities are shared, and lines of authority are poorly defined. A major planning deficiency, directly related to environmental impacts, is the absence of studies on the relationship between the spatial development of Seoul and its transportation system.

A staff group in the Bureau of City Planning possesses most of the expertise in transportation planning. It is an *ad hoc* traffic analysis team which reports directly to the Second Vice Mayor and whose primary responsibility is the identification and solution of short-term problems.

The routing and scheduling of buses, a separate activity, is done by the Bureau of Tourism and Transportation. The location of major facilities in Seoul must receive approval from the Ministry of Construction of the National Government.

The lack of a mechanism that integrates the various elements of the city with its transportation system has been a weakness at the level of policy evaluation and choice, but (in 1973) a Transportation Traffic Coordination Committee was formed to eliminate this problem. In the case of new transportation systems with far-reaching implications, such as mass transit or major highway networks, policy evaluation is particularly called for.

7. Transportation Project Guidelines

In the area of transportation planning, it is generally recommended that 1) integrated systems planning be employed; 2) environmental impact evaluation capabilities be developed, including clearly stated evaluation criteria and assessment of large-scale, long-range technology; and 3) a data base be created in support of these planning areas.

Specific project guidelines for improving the transportation data base include:

-Implementation of small scale, continuous sampling of origin/destination data, with major five-year surveys.

-Regular sampling and recording of air pollution, noise levels, and traffic accidents. It should be noted that a good start has been made in monitoring air pollution, as is described elsewhere in this report.

-Collection of data on transportation services, including time spent in travel, transfer, and waiting. (Present demand analysis methods do not adequately weigh travel time, while placing excessive emphasis on distance.)

-Monitoring social and economic responses to changes in the transportation system.

-Development of an information storage and retrieval system.

The following institutional innovations might also be considered: 1) a strengthened planning agency responsible for the entire urban system, within which a transportation planning unit would be located; 2) an administratively protected environmental assessment unit within the planning agency; and 3) a top level staff group in the agency to evaluate long-term development policy.

To develop the human resources for carrying out the needed work, university transportation training programs must be strengthened, and the possibilities for transportation training at KIST can also be explored. A system for obtaining up-to-date published information from other countries should also be explored. A certain amount of foreign training may be required to provide for immediate manpower needs.

## B. KWANG JU: A SATELLITE CITY EXPERIMENT*

A major feature of the Seoul City Plan for 1970-1980 was the construction and settlement of five or more "satellite cities," approximately 25 kilometers from central Seoul, each of which would house about 350,000 persons. These were devised as a key to the strategy of slowing Seoul's growth rate, which was projected to stabilize after 1981 after attaining a population of approximately 7.1 million. The satellite cities were to bear the brunt of the anticipated population increase that would otherwise be directed at Seoul.

When the first observations were made of Kwang Ju in the course of this study, in June of 1971, it was rapidly evolving as a small city, which despite difficulties, seemed to be going according to plans. Land was still being cleared and streets plotted in anticipation of continued growth. Families were moving in daily. Elementary schools and high schools were built and operating; some electronic industries housed in modern factories were in production, and more industries were planned; a clinic had been opened; and a few small Korean-style inns for travelers were open.

In August, 1971, however, many of the residents of Kwang Ju

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*Originally authored by Dr. Richard J. Coughlin (see Preface).

took part in a mass protest to express their dissatisfaction with conditions in the satellite city, especially with respect to what were interpreted as discriminatory land purchase policies affecting second buyers. On October 14, 1971, the administration of Kwang Ju was transferred to Kyongii Province, and all plans for similar satellite cities were abandoned. Kwang Ju was renamed Sungnam City in 1971.

This section describes the planning and growth of Kwang Ju, the changes that took place, and attempts to evaluate the experience in light of its achievements and failures.

1. The Development of Kwang Ju

Initially, Kwang Ju was intended as a solution to the shanty town problem in Seoul where squatters could be relocated after their dwellings were removed. Squatter settlements erupted in and around the city during the 1960's, especially during the later part of the decade, when population densities in the city were rising toward the 9,800 persons per square kilometer average attained in 1971. The proliferation of these highly visible and embarrassingly ugly settlements not far from the center of the city appears to have been the prime motive for the initiation of a crash urban planning program begun in the late 1960's and the generation of the satellite city plan. However, it was not until early 1971, that the City of Seoul made efforts to develop Kwang Ju into something more than a "dumping ground" for relocated squatters. Thus, there was a discrepancy between the immediate goal of relocating squatters and the long-term goal of the satellite city concept.

The first dwellers in Kwang Ju in 1969 were relocated from Seoul, lured there by the low cost of land and the ten year payment period. Their shanty towns in Seoul were destroyed after they had moved out; but there were no jobs in Kwang Ju at first, and no money for building homes. The first winter was spent by many in make-shift houses and tents. Also, the physical conditions of the city were extremely rudimentary, and the minimum services that were planned were not completed by the time the first settlers arrived. As a consequence, perhaps as much as 50 percent of the original settlers returned to Seoul, and in June, 1973, only 28,000 of the 140,000 persons in Kwang Ju were original settlers. Also, the June, 1973, total was down 60,000 from the estimated 200,000 persons who lived in Kwang Ju in June, 1971.

Minimum preparations and construction in Kwang Ju were carried out prior to settlement, which is consistent with the way town planning has customarily been carried out in Korea. The land was acquired, surveyed, and part of the area cleared by bulldozer of all vegetation; a basic land use plan was devised;

the main entry road was paved; and minimum provisions for water and waste disposal were provided. Then, the area was opened for settlement on 20 pyong* lots. Later, in 1973, lot sizes of 50 pyong and over (100+) were permitted in some cases.

After April, 1970, measures were taken to improve Kwang Ju: the water supply and the roads were improved, jobs in construction were generated (by favoring manual labor over heavy equipment), bus service to Seoul was increased, and tax incentives were extended to business and industry. The last measure triggered land speculation and commercial development. Settlers with attractively located lots were bought out by small businessmen, and the composition of the population began to shift to low income families with some savings who were able and willing to invest in land and a house. To a much lesser extent, white collar, professional and entrepreneurial people also moved into Kwang Ju. Land prices rose and unsold land owned by the city increased in value manyfold. Second buyers were not eligible for the ten year payment period; rather, they had to pay the city the full price. This policy seems to have been the focus of the discontent that lead to the August, 1971 mass protest. Consequently, any profits that the city realized from this policy were paid for to a degree by the political costs of the protests.

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*1 pyong = 3.3 square meters.

By the end of 1972, all planned construction was to have been completed. An open drainage ditch carrying waste water was to be covered and converted into a four lane road; other major roads were to be paved, and water and electricity were to be extended to all sections. However, as of June, 1973, many planned improvements had not yet been made. The main ditch carrying waste water had not yet been paved over; many sidewalks still were not constructed, especially along side roads and lanes; and many roads remained unpaved.

In mid-1973 there were an estimated 10,000 jobs in Kwang Ju, in approximately 100 small industries, whose employees included a large proportion of women. An estimated 13,000 residents were working in Seoul, and most commuted by bus. The trip takes 40 to 50 minutes via a highway completed in 1971.

2. Evaluation

The Kwang Ju experience is somewhat controversial and conclusions as to the degree to which it has succeeded or failed differ, according to differing evaluative criteria. The following discussion attempts to assess Kwang Ju from the standpoint of the City of Seoul's policy to relocate squatters and eliminate slums and from the standpoint of the significance of the experience to other large cities which may contemplate a satellite city policy.

Kwang Ju is a city that is architecturally and spatially similar to other Korean cities with such features as narrow lanes, few playgrounds or green areas, no sidewalks, and traditional house types. The minimum amount of planning and construction undertaken for the city has permitted this pattern of growth. While Kwang Ju does not meet a Westerner's expectations of a model city, its characteristics reflect the development of a community built by rank-and-file Koreans in a style they appreciate and desire.

The fact that Kwang Ju developed into a fairly complete city of 140,000 in four years is indisputably a remarkable accomplishment. It is significant, furthermore, that the city was built by Koreans with Korean resources only. No international agencies were involved.

A summary of the various stages of Kwang Ju's development suggests a procedure which might well be considered elsewhere in the development of new, or satellite, cities.

(a) government buys up land where the future city will be located and develops a basic town plan;

(b) land plots for houses are sold at low cost to poor families and substantial tax incentives are offered commercial and industrial entrepreneurs to locate businesses there;

(c) land speculation is encouraged and poor settlers are enabled to sell out if they wish and use the money received as a cash stake for a better life;

(d) as permanent settlers and businesses arrive, the resulting construction boom generates jobs for lower income workers and additional entrepreneurial opportunities for small scale businessmen, which in turn stimulates increased migration from the nearby urban center;

(e) the government profit realized from the sale of land at highly appreciated prices is used for subsequent communities or for the improvement of existing ones. (How much profit Seoul may have realized on subsequent land sales has not been determined.)

What is the fate of the original poor settlers in this scheme? The Kwang Ju experience indicates that established urban families with low to middle incomes are more successful pioneer migrants than are the urban squatters and rural migrants. Entrepreneurial opportunities attracted the middle income group, while the construction jobs generated by the growing city attracted and held the laboring class migrants.

Kwang Ju demonstrates the minimum planning and zoning approach to new towns. The absence of restrictive zoning enabled the evolution of a culturally representative city. There are, however, disadvantages to the provision of cnly minimum infrastructure prior to settlement. Some of the early settlers were discouraged by the lack of water and electricity. Also as a city rapidly grows, the collection and removal of waste waters via natural drainage systems becomes hazardous and obsolete.

Kwang Ju, or Sungnam's, future growth and urbanization pattern is not clear and no longer hinges on Seoul's policy vis-à-vis squatters and in-migrants, at least from an administrative jurisdictional standpoint. Projections of rapid growth premised on the diversion of new in-migrants to Seoul are no longer valid with the abandonment of a satellite city policy. Yet, rigid enforcement of squatter prohibitions in Seoul may indirectly attract some in-migrants to the extent that commuting from Sungnam to jobs in Seoul is possible. At the least, the city's resident population will have an internal growth rate.

In summary, Kwang Ju did enable the elimination of unsightly slums in Seoul and the relocation of their inhabitants, and it has become an apparently viable small city in a very short time. However, it was only a temporary solution to the slum problem in Seoul to the extent that many of the squatters did move back to Seoul. To what extent those who returned occupied new shanty towns has not been studied. Since the major investment in Kwang Ju was restricted initially to its physical planning and limited infrastructure, its success as a new or satellite city cannot be adequately judged against the more ambitious goals that were implicit in the city scheme. At the present time (1974), the city could be considered primarily as a settlement not for squatters, rather for low income and some middle income families. And these persons have apparently moved from Seoul to Kwang Ju. Thus, Kwang Ju has not proved to be a magnet for incoming migrants, which was the basis of the satellite city scheme.

It can be argued that South Korea's urban squatter settlements perform positive functions that are not readily apparent and which contribute significantly to urban life and the functioning of a city. This proposition is discussed in greater detail in the following section. However, it is relevant here in that an acceptance of the constructive or beneficial role of squatters and squatter settlements throws into question the assumptions and the rationale for a satellite city such as Kwang Ju. The City of Seoul has applied a straightforward criterion to the assessment of Kwang Ju, namely its effectiveness in relocating dwellers of slums which the city wanted to remove. From this viewpoint, Kwang Ju was a success. However, as the cornerstone of a major policy to absorb anticipated, uncontrollable in-migration the satellite city scheme did not last. By this criterion Kwang Ju was a failure.

It can be conjectured that had a more positive view of the social and economic role of poor in-migrants been associated with preparation and settlement of Kwang Ju, the needs of the relocated families would have been better taken into account and more adequate infrastructure as well as more job opportunities would have been provided. Had this been the case, the economic and social viability of the new city would have been enhanced. However, because the City of Seoul did not make an irreversible commitment to the satellite city scheme, the problems encountered in Kwang Ju did not result in a major disaster. Viewed positively, the lessons to be learned from the history of Kwang Ju are of great potential value to future planning of new cities, and to the consideration of this alternative for solving the problem of slums and squatters in big cities.

Research is needed, however, in order that we may learn from the Kwang Ju experience. More data is needed on intra-city migration in order to determine to what extent squatters advance from slum settlements to better housing and jobs, and on the factors which influence social and economic mobility. It has been found in Korea and other Asian cities that shanty towns serve as a "conditioning milieu" where rural migrants can become accustomed to city life, live inexpensively while seeking employment, and begin an urban life style. In this process, some migrants move from squatter settlements to better housing in other areas while some remain and improve their houses and neighborhoods.

Changes in the economic status of Kwang Ju's population should also be studied in order to better establish the efficacy of the city in attracting and holding poorer residents. This has been done to only a limited degree according to the information available. In Malaysia, a new planned community outside Kuala Lumpur similarly attracted higher-income persons rather than squatters or laborers. It could be hypothesized that the resettlement of middle-income people from the primate city to satellite cities makes room for upwardly mobile squatters in the primate city.

The sociological impact of certain aspects of life in Kwang Ju should be examined. Industry seemed to favor female employment with possible adverse consequences to family stability and childrearing. Also, a study should be made of the impact of Kwang Ju on the adjacent rural zone and its potential as a catalyst for rural-urban migration.

The needed studies will require more support and cooperation from the City of Seoul than has been the case to date. Research needs to be organized more efficiently. There is little communication and sharing of data. These impediments must be eliminated if town planning in the Republic of Korea is to realize its potential.

Many other nations in Asia are experiencing problems of uncontrolled urban growth in primate cities, like Seoul, but the Republic of Korea, unlike the majority of Asian countries, is favored in having an ethnically homogeneous population, a long-range and comprehensive plan for urban growth, the intention to implement this plan, and town planning and social science talent in the government and at universities of a very high order.

## C. MIGRATION AND SQUATTER SETTLEMENTS IN SEOUL*

This section treats the relationship of economics and migration in Seoul. It also considers both present and planned policies and programs for squatters. After setting forth findings, an evaluation of measures aimed at squatters is made. Finally, general principles are postulated.

### 1. Migration

Between 1960 and 1970, contribution of in-migration accounted for increasing amounts of Seoul's total population which approached an average of 1,000 persons per day. In-migration during this decade made up over 80 percent of the growth. Since 1970, the in-migration has apparently slowed because of slackening construction and worker demand, strict prohibitions on new squatter housing, including aerial photo surveillance, and better jobs and wages in rural areas. But in-migrants also have non-economic motives, usually better education. This latter motive is responsible for an important current in-migration of middle income families.

The nation's extraordinary industrial growth rate during 1960-70 (approximately 20 percent per year) absorbed the flow of migrants. Wages increased during 1967-70 by 38 percent per year. Until the 1970-71 recession, unemployment or underemployment were

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*Originally authored by Dr. Joan M. Nelson (see Preface).

not problems. A trend to capital intensive production and slower economic growth could generate unemployment. However, recent government policies have renewed economic expansion and point towards an accelerated economic growth (The Oriental Economist, 1973).* In addition to measures taken to promote heavy and chemical industries and export trade, rural development through the Saemaul (new community) program will receive added impetus in 1973-1974 from an increased budget. Both new industrial jobs and more job opportunities in the countryside should result, thereby helping to stem the flow to Seoul of job-seeking in-migrants.

2. Squatter Settlements

There are an estimated 165,000 squatter dwellings in Seoul housing perhaps 1,500,000 persons, and representing 28 percent of the 597,000 housing units (1970 census). Most squatter units have a tenant family in addition to the owner family. Roughly 120,000 units were estimated to lack land title, while others are illegal because of faulty construction or nonregistration. Most squatting is on public land, including planned sites for roads and parks. Thirty percent of the squatter houses are scattered singly or in small clusters throughout the city, and the remainder are concentrated either at river edge locations or on the steep, rocky hills

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*This evaluation was formulated prior to the petroleum shortage in late 1973, which hit Korea in special severity because its industry is heavily dependent on oil and petro-chemicals. (Editor) in the city. The hill settlements are usually in better condition and more stable than the river edge shanties. Some riverside squatter houses were carried away by floodwaters in 1972 and reconstruction has not been permitted.

Various efforts have been made to cope with squatters. Four hundred and fifty low-cost apartment buildings were constructed during 1970-73, partly on land formerly occupied by squatters. Dislocated families were given preference in the sale of partially completed apartment units. Down payment was 200,000 won*. However, rapid deterioration has characterized these "citizen" apartments. Costs of finishing the units, borne by the relocated families, were high, and many of the former squatters moved out.

As a strategy for relocating squatters out of Seoul, Kwang Ju was also a dubious success. There were insufficient jobs, public transportation to Seoul was initially entirely inadequate, and water and sewers were not hooked up. The result was that many former squatters returned to Seoul. By 1973, however, employment opportunities had improved considerably with the establishment of some 100 small industries.

3. Current Policy on Squatter Settlements

Current policy toward squatter settlements has three prongs:

(a) New squatter construction is prohibited. The prohibition

*U.S. $1.00 = 400 won in 1973.

is vigorously and successfully enforced. Aerial photographic surveillance, made at three-month intervals, is employed to discover new buildings, which if found are razed. Local officials responsible for enforcing the prohibition are fired if new illegal houses are discovered.

(b) Some squatter settlements will be legalized. Under current criteria, roughly thirty percent of the existing squatter housing is eligible for legalization. Eligible communities will first improve their storm drainage and widen their roads with some assistance from the city government. They must then reallocate and consolidate lots so as to satisfy city requirements of minimum lot size. The city requires lots to be at least two to three times larger, approximately, than the average in existing settlements; therefore, more than half the residents will have to sell out, or double up with neighbors. Existing houses will also have to be remodeled or replaced to conform to city requirements. Having met these conditions, each resident will be permitted to purchase from the government the land on which his house stands.

(c) Squatter settlements not eligible for legalization will eventually be eradicated and their residents relocated. The city plans to move as gradually as possible on eradication.

4. Are Squatters Assets or Liabilities?

Squatter settlements and their populations are viewed favorably (or sympathetically) or unfavorably by city and national officials and these views together with their supporting arguments underlie differences in approach to the most appropriate policies for squatters.

It is notable that until 1973 the City of Seoul had no housing policy. In July of that year, the Bureau of Housing was formed within the metropolitan government. Prior to that time, the city's policy, described above, was premised on the undesirability of squatter settlements owing to their embarrassing and visible squalor. This policy had not changed as of August, 1973.

The elimination of squatter settlements and the removal of their populations from Seoul raises the question of the social value and the human dilemma of these people, which are considerations primarily of concern to university researchers rather than city officials. The Smithsonian consulting scientists shared this concern. Squatter populations represent a pool of low-cost labor which contributes in an unmeasured extent to the construction in-industry, and to the performance of menial services such as the transport of goods, the collection of city wastes, and the salvage of usable wastes. In addition, the human problems of squatters living on a survival basis are of sociological significance, which is heightened by their sheer numbers. The level of living and precariousness of life has obvious negative consequences to physical and mental health and the integrity of the family unit. Paradoxically, and notwithstanding the adversities of squatter life, squatter settlements show surprising community spirit and cohesiveness, especially in contrast to the "citizens" apartment communities.

One practical consideration, so far overlooked in measures to deal with squatter settlements, is that many houses are occupied by both the original settlers and even poorer tenant families who cannot afford to build. These tenants may constitute as much as 50 percent of the total, and relocation schemes which provide incentives to families to move out have neglected the even poorer tenants.

The various views and concerns shared by Korean university sociologists and students of urban problems argue against a policy of squatter elimination and removal. They argue that squatter populations should be seen as a necessary transition in urbanization. To accept existence of these communities on this basis recognizes their positive role as well as their special needs. This implies the need for policy measures oriented to social and economic development rather than measures which call for elimination and removal.

It is clear that the conflicting premises underlying existing and recommended policies need to be substantiated by demographic, social and economic research into the status and role of squatter settlements and their populations.

5. Specific Policy and Research Guidelines

The following guidelines were suggested by Dr. Nelson for consideration particularly in regard to the legalization scheme, and also in regard to needed research.

(a) Criteria should be changed to permit small clusters of squatter dwellings to be eligible for legalization. At least thirty percent of squatter housing is ruled out by the present criterion.

(b) Settlements located on hills over 100 meters above sea level are not eligible under current criteria. This excludes many of the most cohesive squatter communities. The major reason for the regulation is the difficulty of pumping water to the higher settlements. The construction of reservoir tanks on high ground could solve distribution problems; however, special high pressure pipes would have to be provided to prevent the leakage that presently occurs in the low pressure water lines. Provisions would also be needed for removal of waste water and human wastes.

(c) The squatter legalization process can be streamlined by abandoning the effort to control lot and house sizes. Unlike the requirements for storm drainage and road access, these controls are not necessary for minimum community environmental standards. They add substantially to the costs of legalization borne by the squatters, and will therefore increase the proportion of those who will be unable to afford legalization even if their communities are eligible. (The city estimates that 20 percent will be unable to afford the process, but other data suggest that a much higher proportion will be forced out.) Insistence on high minimum lot and house sizes could also negatively affect community cooperation necessary to carry out needed community improvements, and create a division of interests between "rich" and "poor" squatters. Finally, the planned regulations impose a heavy enforcement burden on the already overloaded city government.

If these recommendations were adopted, legalization would require only two steps: (1) construction of necessary community improvements, and (2) individual purchase of land from the government.

(d) For squatters displaced from eradicated settlements and for those from communities eligible for legalization who cannot or do not wish to purchase title, alternative forms of assistance, in addition to removal to a lot in the outlying sections of the city, should be developed. Some squatters might prefer a low-cost loan to finance the <u>chonsei</u> (key money) payment for rented quarters. Such loans might be less costly to the city than providing all displaced squatters with lots.

(e) To develop institutional capacity to analyze squatter problems, it is recommended that existing university research and training entities be encouraged to offer workshops on problems of squatters and of low income neighborhoods for city and national officials. In this connection, the research capacity of the city bureaus should be strengthened. The development of fruitful cooperation between the city government and academic institutes should be promoted.

(f) Two research projects are suggested to improve information on migration into Seoul. The first concerns the effects upon migration of farm mechanization which can be expected to spread rapidly in the next decade. The second study would use a purposive sample, rather than a stratified random sample, to study the motivations and experience of specific categories of migrants into the city. The categories would be selected because they pose policy problems and would not necessarily represent a cross-section of the migrant population as a whole.

(g) More research on the costs and benefits of encouraging the growth of medium-sized cities is also urged before any decisions are made to embark on such a policy.

6. General Implications for Policy Formulation and Planning

The problem of squatter settlements should not be regarded solely as a problem of city planning and low-cost housing. Squatting is an important element in the economic and social integration of low income people into the city. Many squatter families will be worse off, not better off, if they are provided better housing when they are located at a distance from the job of the breadwinner. Such families cannot pay high rents. In other words, relocation schemes are costly to the squatters as well as to the city. Programs can be designed which will alleviate some of the specific problems caused by squatting, such as risk of fire or important health hazards, without extensive eradication and relocation. Where relocation is necessary to free land for urgent public uses, relocation provisions should be flexible to meet varying life circumstances of different households.

Legalization schemes can concentrate on upgrading community facilities and environment and should not attempt to regulate individual lots and houses. In newly forming settlements, however, regulations on lot size (density) are desirable, if administrative mechanisms are capable of enforcing such regulations.

Finally, it should be noted that migration and squatting are simple labels for complex phenomena. Some aspects of squatting and some aspects of migration do cause problems which the city government must address. But much migration is inevitable in terms of developmental goals, and without airtight enforcement, squatting is also inevitable. The first step toward realistic policy is to identify as precisely as possible those aspects or categories of migration and squatting which pose serious problems. Appropriate policies can then be designed to address these narrower, more manageable problems.

Desire for modernization, orderly growth, and high aesthetic standards can lead to over-emphasis on architectural design, engineering standards, and rigid land-use planning. Urban redevelopment programs in the United States during the 1950's, undertaken in the name of more attractive and healthful cities, dislocated large numbers of low income families without providing realistic alternatives for their accomodation. Some attitudes in Seoul are similar enough to those in the United States in the 1950's to cause concern that serious American mistakes may be repeated in Korea. Other developing nations may have similar tendencies.

The desire to maintain high standards should not be used to justify unrealistically rigid standards for legalizing squatter settlements. Unrealistic criteria not only hurt legalization programs, but also divert attention from more realistic problems and encourage corruption and evasion of the laws.

## D. WATER SUPPLY AND WATER POLLUTION*

Past and projected developments of water supply for Seoul and the particular problems of water quality were studied. Methods for waste disposal were investigated primarily in terms of the associated polluting effects. The question of the best and most economical system for treatment of human excreta is a particularly important one that concerned the author. This same question was directed at India in a September, 1971, workshop (Water and Man's Life in India) sponsored by the Indian National Science Academy and the U.S. National Academy of Science. The author participated as a member of the NAS panel. At that meeting, there was a general consensus that wastewater collection and disposal systems were too expensive for many of the developing countries, and that other disposal methods should be seriously considered.

### 1. Introduction

History suggests that in the absence of a water carriage system, waste disposal has always been a difficult, if not impossible, task. And keeping wastes from storm sewers, when built, was an equally impossible task.** Seoul's experience

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*Originally authored by Dr. Perry L. McCarty (see Preface).

**In Europe, early sewers were frequently the channels of the natural drainage systems, but human waste was collected in confirms these observations. Like the growing cities in Europe and the United States in the last century, Seoul has a storm sewer system imposed on the natural drainage system, no wastewater treatment, and no water carriage system for collecting human excreta. However, unlike western cities a century ago, Seoul is much larger, with 6 million inhabitants, a central city that is rapidly growing vertically, and, in general, has conditions that greatly complicate conversion to a water carriage system with wastewater treatment. Interim solutions are being employed, however.

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cesspools. There were 2 schools on the question of collecting human and other organic wastes from the cesspools: the "dry" and the "water carriage" methods. In the dry method, the concentrated waste was dried on soil beds or disinfected by calcium chloride or other chemicals. The product was usually used for fertilizer. The water carriage method was not popular at first, but as sewers became increasingly foul from other refuse washed off the streets, opposition to discharging fecal matter into the waterways dwindled. Also in large cities, such as London, the absence of effective collection and removal of waste and filth led to epidemics in the mid-19th century. To clean up the city, systems of intercepting sewers were constructed to collect drainage and wastewaters and discharge them downstream.

In the United States, a similar evolution from cesspools to sewers occurred. In Philadelphia, the discharge of home wastes into sewer lines was prohibited up until 1850. The last city in the United States to banish cesspools in favor of the water carriage system was Baltimore, in 1879. However, it was apparent that before that date many of its 80,000 cesspools were overflowing into the sewers, notwithstanding laws to the contrary.

2. Seoul's Water Supply

The major source of city water is the Han River, one of the largest in Korea, with a drainage basin of 33,000 square kilometers, slightly more than one-fourth the area of the Republic of Korea. Flow is markedly seasonal, reflecting the concentration of precipitation in the basin in the months of June through September. Sixty-five percent of the annual run-off occurs during July to September. In addition to supplying water to the City of Seoul, Han waters irrigate 126,000 hectares, mostly rice, and 5 dams with hydropower plants have been built in the basin.

Seoul City obtains most of its municipal water from the Han River, relying on groundwater for the remainder. However, partly because of Han River pollution at the present intakes, there are active plans to move the intakes upstream to the Paldang Dam. Downstream from Seoul, Inchon also uses Han River water as do many industries in the Seoul-Inchon area. It is estimated that about 970 million cubic meters of water were being diverted from the Han River for municipal and industrial purposes in 1970. The annual precipitation and runoff in the basin produces about 18,060 million cubic meters of water just upstream from Seoul, or double the 1970 rate of consumption.

Fluctuations in the flow of the Han are shown in Figure 2 and Table 4, as measured at a point 20 kilometers above Seoul (the Ko-An Gauging Station). The projected water consumption

Figure 2

Han River, Korea. Ko-An Gauging Station

Mean Monthly Discharge in Cubic Meters Per Second

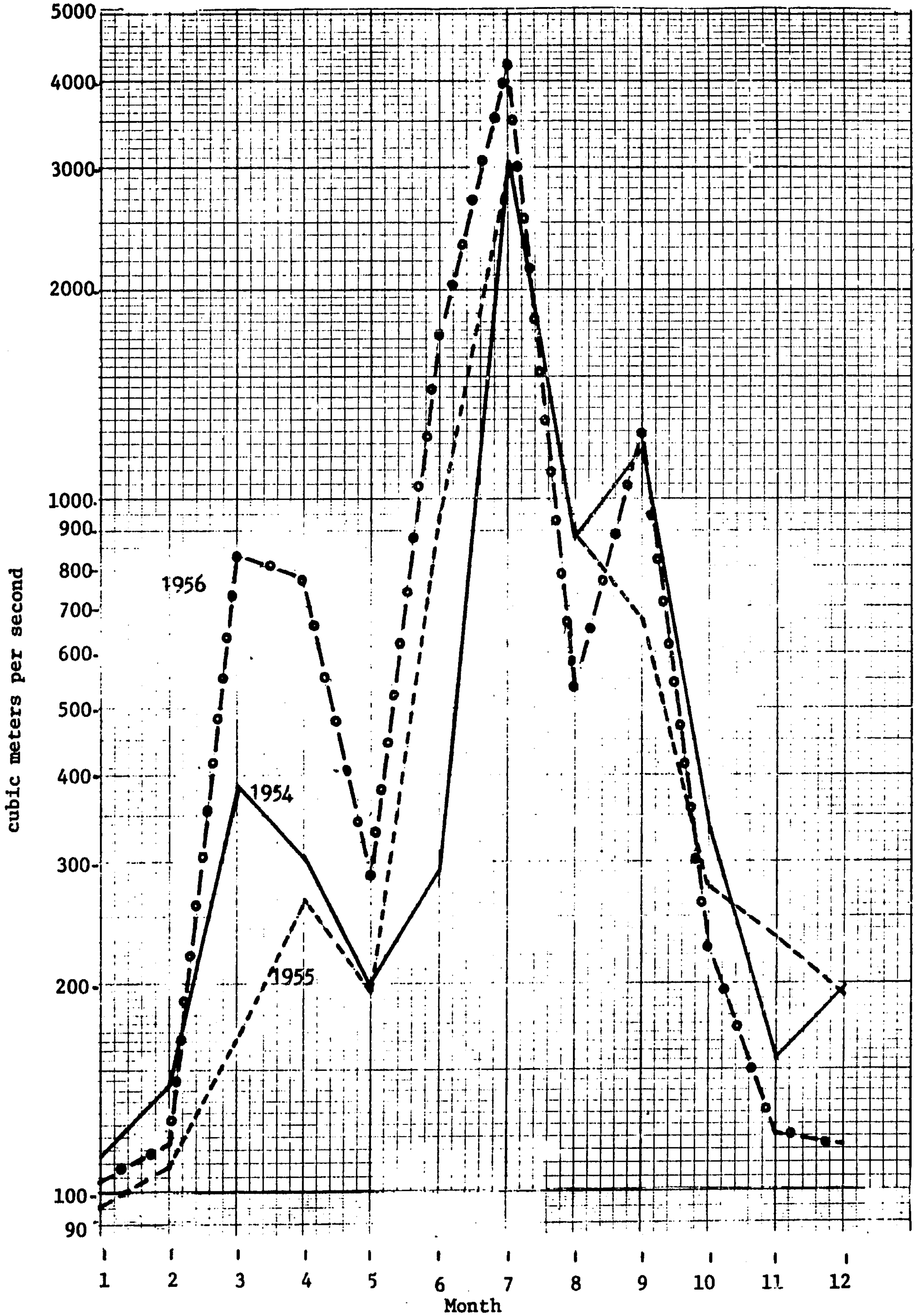

Table 4

Minimum Drought Flow, Ko-An Gauging Station

Average Minimum 7-Day Consecutive Flow

| Year | Flow, Cubic Meters Per Second |
|---|---|
| 1917 | 31.06 |
| 1918 | 29.93 |
| 1919 | 33.04 |
| 1920 | 30.78 |
| 1921 | 41.23 |
| 1922 | 38.37 |
| 1923 | 32.87 |
| 1924 | 38.32 |
| 1925 | 51.99 |
| 1926 | 84.54 |
| 1927 | 79.91 |
| 1928 | n.d. |
| 1929 | 57.58 |
| 1930 | 72.68 |
| 1931 | 65.12 |
| 1932 | 86.52 |
| 1933 | 52.55 |
| 1934 | 66.61 |
| 1935 | 65.06 |
| 1936 | 44.93 |
| 1937 | 78.47 |
| 1938 | 62.12 |
| 1939 | 65.06 |
| 1940 | 50.91 |

Source: The Government of the Republic of Korea. 1963. Application for AID Development Loan: (Bokwang-Dong Water Works Project): Part I, Feasibility Study.

in 1981 for Seoul of 3.08 million cubic meters per day (Table 5) is equivalent to a flow of 35.73 cubic meters per second. Assuming that the greater part of Seoul's water continues to be taken from the Han River, it seems unlikely that needs cannot be met even at low flow.

Intrusion of saline water may pose problems. Seoul lies near the outlet of the Han River into the Yellow Sea. Under low flow conditions in the river, seawater can intrude up the river to Seoul decreasing water quality at the water intakes. A flow of 150 cubic meters per second in the Seoul area is sufficient to keep the seawater below the city limits; but when the flow drops to 75 cubic meters per second, significant seawater intrusion occurs. During the period 1917 to 1940, 16 out of 20 years experienced an average minimum flow of less than 75 cubic meters per second during a 7-day period.

There are presently 5 water treatment plants which draw water from the Han River and have a combined capacity of 1,167,000 cubic meters per day. There are four supplementary treatment plants using groundwater with a combined capacity of 130,000 cubic meters per day. The treatment plants are modern in design using chemical treatment, settling, filtration, and chlorination prior to distribution. The capacity of the plants is continually being increased to parrallel water demands.

The portion of the population served by the municipal water supply and the per capita water usage, past and projected, are listed in Table 5. Although water rationing has been necessary in recent years, the capacity is now believed to have expanded to the point that rationing will be necessary only during severe drought conditions. The estimated industrial water usage in the city is 60,000 cubic meters per day, which is relatively low.

Table 5

Past, Present, and Projected Water Consumption in Seoul

| Year | Population of Seoul (Million Persons) | Water Production (Thousand $M^3$/day) | Percent Population Receiving | Water Per Person (Liters/day) |
|---|---|---|---|---|
| 1951 | 0.65 | n.d. | 75 | n.d. |
| 1961 | 2,58 | 290 | 56 | 201 |
| 1970 | 5.54 | 1110 | 86 | 234 |
| 1976 | 7.15 | 2280 | 92 | 347 |
| 1981 | 7.50 | 3080 | 95 | 432 |

The cost for water is listed in Table 6 and reflects a progressive scale. The more water that is used, the higher the cost. This is an unusual rate structure, but a desirable one as it discourages wastage of water while making it readilv available to the poor at a low cost.

Table 6

Charges for Water, 1972

| Nature of Use | Increment of Use $M^3$/month | Water Cost (Won/$M^3$) |
|---|---|---|
| Household: | less than 10 | 150 (total) |
| | 11 - 20 | 15 |
| | 21 - 30 | 20 |
| | 31 - 40 | 30 |
| | more than 40 | 40 |
| Business: | less than 30 | 1,350 (total) |
| | 31 - 200 | 70 |
| | 201 - 1,000 | 90 |
| | more than 1,000 | 120 |
| Public Bath: | less than 600 | 48,000 (total) |
| | 601 - 1,000 | 100 |
| | 1,000 - 3,000 | 160 |
| | 3,000 - 12,000 | 200 |
| | more than 12,000 | 250 |

Water is supplied both directly to individual dwellings and also to community taps (Table 7). All water is metered. The community taps are operated by local residents and charges are made depending upon the size of the container in which water is carried. The quantity of water available seems adequate to serve the present needs.

Table 7

Water Supply Facilities, 1965-1970

| Year | Population (Thousands) | Households (Thousands) | Percent Serviced Population | Percent Serviced Households | Number of Faucets (Thousands) Total | Domestic | Public Use |
|---|---|---|---|---|---|---|---|
| 1965 | 3,470 | 338 | 73 | 70 | 206 | 190 | 1.02 |
| 1966 | 3,800 | 368 | 71 | 70 | 226 | 205 | 1.05 |
| 1967 | 3,970 | 298 | 75 | 73 | 251 | 226 | 1.20 |
| 1968 | 4,330 | 837 | 79 | -- | 267 | 240 | 1.27 |
| 1969 | 4,780 | 961 | 86 | 85 | 305 | 275 | 1.39 |
| 1970 | 5,540 | 1,000 | 86 | 77 | 329 | 296 | 1.63 |

Source: Seoul Statistical Yearbook, 1971.

3. Water Quality

Presently the major problem in water supply is that of quality. The river water upstream from Seoul is of excellent quality; however, wastewaters running from the city are presently discharged untreated into the Han River and as the river flows through the city it becomes grossly polluted. The water intakes for water treatment plants are located downstream from significant sources of pollution. Difficulties have been experienced in treating the water to an adequate degree, but improvements have been made.

Only in recent years have good data on water quality of the Han River been collected. In 1965 measurements began at three of the major water intakes--Goo U Ri, Dook Do, and Noryang Jin (Fig. 3 , Nos. 1, 2, and 4). Characteristics measured included temperature, turnbidity, pH, total alkalinity and acidity, COD, chloride ions and total coliform. Similar data for the other two intakes--Bok Kwang Dong and Yongdeung Po (Nos. 3 and 5, in Fig. 3 )--have been collected since 1971. Data from measurements in 1972 at all five intakes are summarized in Table 8, and Table 9 shows trends in certain characteristics during the period 1965-1970. During those years, water quality was declining and the trend has continued as indicated by data for 1971 and 1972. Maximum coliform counts have been very high at most of the intake points (see Appendix C), but especially at Bo Kwang Dong. Also Table 8 illustrates how the water quality of the Han worsens as it flows through the city.

The raw water for the Bokwang Dong Water Treatment Plant is obtained just downstream from the discharge of the Chong Gye Chun River, a major source of wastewater, and is therefore of poor quality. When the treatment plant was visited by Dr. McCarty in June, 1972, the raw water was laden with very large growths which appeared to be Sphaerotilus type organisms. These organisms grow attached to rocks and sediments in heavily polluted streams and were apparently being scoured from the river bottom and pulled in at the water intake. The water was being chlorinated before and after treatment, as it should have been, in order to insure the safe disinfection of the supply.

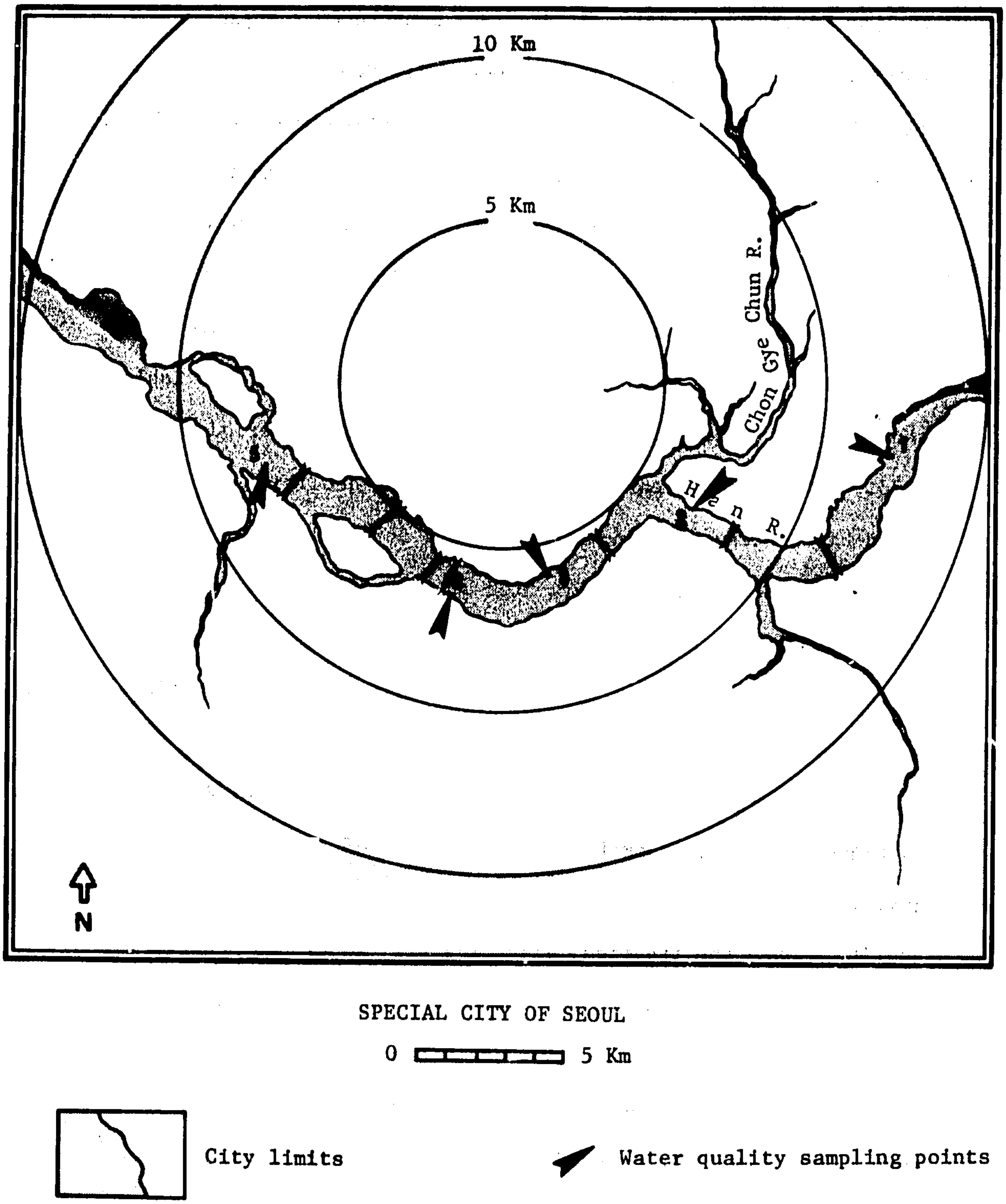


Figure 3. Water Quality Sampling Points, 1973.
(See Appendix C for water quality data.)

Table 8

Water Quality Characteristics of the Main Han River, Seoul, at the Five Major Intakes, January-December, 1972

| Item | (1) Goo U Ri | | | (2) Dook Do | | | (3) Bo Kwang Dong | | | (4) Noryang Jin | | | (5) Yongdeungpo | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Ave. | Min. | Max. | Ave. | Min. | Max. | Ave. | Min. | Max. | Ave. | Min. | Max. | Ave. |
| Temperature °C | 2.0 | 25.0 | 11.78 | 2.5 | 25.0 | 12.83 | 3.0 | 25.0 | 13.3 | 2.5 | 25.0 | 14.55 | 3.0 | 30.0 | 16.21 |
| Turbidity | 2.0 | 24.0 | 6.66 | 2.0 | 24.0 | 8.0 | 14.0 | 26.0 | 18.08 | 12.0 | 24.0 | 16.41 | | | 26.0[1] |
| pH | 7.0 | 7.4 | 7.23 | 6.9 | 7.3 | 7.21 | 6.7 | 7.4 | 7.16 | 6.7 | 7.4 | 7.18 | 7.0 | 7.3 | 7.08 |
| Total Alkalinity | 21.0 | 46.0 | 35.71 | 30.0 | 50.0 | 44.5 | 34.0 | 65.0 | 49.57 | 30.0 | 52.0 | 45.00 | 30.00 | 75.0 | 50.08 |
| Total Acidity | 2.0 | 4.8 | 3.25 | 2.0 | 5.8 | 3.54 | 3.5 | 8.4 | 4.98 | 4.0 | 6.3 | 4.75 | 3.0 | 9.5 | 5.93 |
| Dissolved Solids | 72.0 | 120.0 | 88.0 | 76.0 | 140.0 | 97.80 | 98.0 | 240.0 | 141.80 | 89.0 | 180.0 | 125.6 | 160 | 260 | 193.33 |
| Suspended Solids | 10.0 | 153.0 | 76.75 | 10.0 | 148.0 | 66.5 | 50.0 | 236.0 | 127.00 | 40.0 | 188.0 | 97.75 | 40.0 | 256.0 | 111.00 |
| DO (mg/l) | 7.5 | 13.6 | 9.93 | 6.9 | 13.6 | 9.85 | 2.3 | 12.0 | 7.85 | 3.3 | 11.0 | 8.30 | 1.0 | 10.6 | 7.39 |
| BOD (mg/l) | 1.2 | 3.1 | 1.81 | 1.5 | 3.5 | 2.48 | 4.0 | 14.7 | 9.27 | 4.2 | 11.8 | 8.01 | 4.8 | 20.0 | 10.50 |
| COD (mg/l) | 0.4 | 1.3 | 0.89 | 0.5 | 1.7 | 1.04 | 1.0 | 3.3 | 2.18 | 0.8 | 2.7 | 1.87 | 0.8 | 7.1 | 2.78 |
| Chloride Ion (mg/l) | 5.3 | 7.7 | 6.73 | 1.6 | 8.5 | 6.23 | 6.2 | 17.0 | 12.43 | 4.9 | 12.8 | 10.15 | 2.6 | 24.1 | 13.55 |

[1]Only one measurement, in September

Source: Water Pollution Monitoring Station, Hygiene Laboratory, Seoul Metropolitan Government

Table 9. Biological Oxygen Demand and Coliform Count in the Han River at Three Major Water Intake Points, 1965-1970.

| | Upstream | | Downstream | |
|---|---|---|---|---|
| | BOD mg/1 | Coliform count/100cc | BOD mg/1 | Coliform count/100cc |
| 1965 | 0.6 | 440 | 2.3 | 50,000 |
| 1966 | 0.9 | 525 | 2.8 | 61,000 |
| 1967 | 1.3 | 735 | 3.2 | 80,000 |
| 1968 | 1.7 | 1,200 | 5.6 | 87,000 |
| 1969 | 2.0 | 1,770 | 7.8 | 100,000 |
| 1970 | 2.5 | 2,540 | 11 | 123,000 |

Source: Bureau of Water Supply, Special City of Seoul.

Although Dr. McCarty heard expressions of concern during his 1972 visit about turbidity andodor of treated water, these are no longer considered to be problems. Odor and taste are routinely monitored and when needed are corrected with chlorination. Interim solutions for human waste treatment, described below, will reduce the load of raw human sewage in the river until such time as water treatment plants are installed.

The 1972 data are obviously the best baseline data, which will serve as a point of departure for monitoring trends in the Han River water quality in the vicinity of Seoul. Data from that year do not indicate serious water pollution problems. It is notable, however, that samples were not analyzed for fecal coliform. This test would indicate to what extent human wastes are posing a public health and water treatment problem. In any event, concern over Han River water quality was an important factor in the decision to move Seoul's water intakes upstream to the Paldang Damsite.

4. Wastewater Collection and Treatment

Wastewaters flow out of the city and into the Han River via the natural drainage system, which is comprised of four major stream basins in the city itself. The Chong Gye Chun basin is the largest (5,631 hectares) and most built-up, and includes the government office buildings of both the city and the Republic of Korea. Currently, wastewaters are not treated. (The first sewage treatment plant is to be completed in late 1974 on the Chong Gye Chun stream.) As a result, the Han River is grossly polluted, is unfit for swimming and may constitute a barrier for anadromous fish that migrate from the sea to freshwater spawning areas. It was not determined whether such fish are commercially important; however, catadromous eel, or elver, is commercially important. It spends its adult life in the Han and spawns in the ocean.

The construction of drainage ditches and canals appears to have come about in an unplanned fashion as has been the case historically in most cities. Ditches have been built from the houses, along the streets, and then to natural drainage canals which eventually reach the Han River. With time these ditches have become more formalized; some have been lined and others are now covered. The major portion of the Chong Gye Chun River passing through the city has been covered and in one stretch a major highway has been built over it.

During the dry season of the year, the major flows in the streams and rivers appear to result from water which has been used for household, commercial, and industrial purposes. The rivers and streams that flow from Seoul during the dry seasons contain little other than sewage. This is very true of the water flowing in the Chong Gye Chun River. The organic content of this river, measured in terms of the biochemical oxygen demand (BOD), is about 250 mg/l. In the USA the average BOD of domestic sewage is approximately 100 to 300 mg/l, and by this standard the Chong Gye Chun falls into the category of an open sewer. However, its discharge is greatly diluted when it mixes with the Han River, as indicated by the relatively low average BOD of 9.3 mg/l of samples taken in 1972 at Bokwang Dong intake, approximately 5 kilometers below the mouth of the Chong Gye Chun.

A modern sewage treatment plant, presently under construction at the lower end of the Chong Gye Chun River, is to have a capacity of 250,000 cubic meters per day. The process is to be of the secondary or activated sludge treatment type and is anticipated to reduce the BOD from 350 ppm to about 20 ppm. This plant is to be completed in 1974.

The city has plans to build additional treatment plants at the end of the major streams draining the other three basins in the city. Although plans have been made to construct a system of sewers, no extensive system has yet been built. The Chong Gye Chun treatment plant will simply divert water from the river through the plant for treatment. Use of limited funds to initiate construction of a treatment plant without a sewer system might seem strange, but construction of a modern sewer system would be much more expensive than building the treatment facilities only. The future plans do not include an intercepting sewer that would pick up the wastes from the different portions of the city for transport to a single treatment plant even though this is a common method used in many Western cities. The cost of an intercepting sewer is, of course, quite high, especially in a city already so developed, and this tends to make the proposed system seem reasonable.

There is no doubt that the Han River is currently very polluted by the wastes discharged from Seoul. In 1970 water analyses (Table C-6) suggest that the quantity of wastes contained in the Han River are equivalent to the wastes from a population of about 5 million. It also suggests that night soil collection and disposal is of relatively minor importance in reducing the quantity of pollution reaching the Han River. The concentration of coliform organisms in the Han River, an indicator of contamination by human wastes, is extremely high and also suggests that night soil collection is of little real significance in reducing the pollutional effects of waste discharge from the city. Thus, night soil collection and disposal might be looked upon mainly as a convenience and a way of handling the human wastes from a city at minimum costs, but not as a method for preventing serious pollution of the rivers. Although night soil collection is improving as described below, the lack of coliform analyses in the 1972 data does not permit an evaluation of the effects on Han River water quality.

a) Industrial Water. The City of Seoul has many small cottage type industries scattered throughout the city. While a few large industries are located within or upstream of the city, the major industrial complex is located across the Han River from the main center of Seoul, along the corridor between Seoul and Inchon. The major industries are located along the An Yan River which discharges into the Han River at the lower end of Seoul. The limited data which could be found for this river suggested that it is grossly polluted; but because the discharge is downstream from the city, there seems to be little concern over its effects. The Han River downstream from Seoul forms the border between North Korea and the Republic of Korea, so that at present concern over downstream water quality appears minimal. From a water pollution standpoint, it is fortunate for the city that industry became located in the area it has, whether by luck or by design. For this reason, the major water pollution problems in Seoul itself relate to the discharge of municipal and commercial wastes, and fairly little from the discharge of industrial wastes. This is perhaps quite unusual for a city of this size and should not be considered as typical of all cities.

b) Night Soil. The collection of night soil in the city has been both a health and water pollution problem. In the past, night-soil has been discharged directly into the Han River, but collection has improved recently. While the portion entering the Han has been reduced to approximately 10 percent, the absolute amount has not decreased substantially in recent years. Table 10 compares the treatment of night soil for 1971 and 1973.

Table 10

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.

Use of flush toilets has increased and greater amounts of night soil are collected for disposal and some treatment in large holding basins, termed disposal tanks. Use as fertilizer has declined considerably.

Direct discharge of human wastes into rivers, streams or sewers is not legal, but has been difficult to prevent. To alleviate this problem a scheme has been initiated to improve toilets. It will be carried out by teams working at the district level with powers to prosecute if necessary. A key to this effort is an amendment in the construction law which requires dwellings to have holding tanks. The problem testifies to the difficulty which has been experienced historically in efficiently collecting all the night soil from a city in the absence of collector sewers.

Collection of night soil from holding tanks is either manual or by means of suction into trucks equipped with vacuum pumps. Manual collection is done about once a month. The excreta is scooped from the holding tanks or latrines with buckets and carried to trucks of about 4,500 liter capacity. It is then transported to large disposal/treatment basins four to eight kilometers from the city where it ferments. The fermented product is then discharged into the Han River, although the latter is done only during the rainy season. Only one of the basins is located near the Han River. During the early spring when fertilizer demand is high, some of the fermented night soil is applied directly to orchards and other farms on the outskirts of Seoul. This was observed by Drs. Bowerman and Hall in 1972, but this practice is declining, in part due to the cost of transport. Solids are skimmed from the disposal basins for drying and sacking, and are then sold as fertilizer in straw sacks for approximately 80 won (U.S. 20 cents) per sack.

Collection of night soil by vacuum trucks is increasing. Twenty-five percent of the dwellings in Seoul were serviced with these trucks in 1971, while in 1973 an estimated 50 percent will be serviced. By 1975 it is expected that 80 percent will have vacuum truck collection. Because of inaccessibility of dwellings in narrow lanes, 80 percent is about the limit. The cost of vacuum service is 15 won (U.S. $0.04) per 20 liters for either dwellings or large buildings. This method of collection will help eliminate the sanitation problems of manual collection with buckets, which inevitably spills. Dwellings inaccessible to vacuum trucks could possibly be serviced by means of portable extensions of the hoses. However, lines would need to be very long in some areas, and such a solution may not be feasible.

Sanitation problems also exist at the disposal basins. Although fermentation requires 15 to 30 days, temperatures are not high enough to kill the eggs of parasites. The surface is said to freeze over during the winter. Even after several months, crops can be contaminated if fertilized with this material. Ground water undoubtedly is also being contaminated, especially in the vicinity of the disposal basins.

A two-phase plan has been prepared to deal with the treatment problem: initially, expansion of treatment by wet-oxidation combustion, and at a later stage, conversion to digester treatment as the construction of collector sewers proceeds. A total of six treatment plants is planned, each with a capacity of 600 kiloliters per day. One was inaugurated in 1972 and is running well; another is under construction. Four more will be constructed to bring total treatment capacity to 3.6 million liters per day. This will take care of the major proportion of the daily night soil production of 4.8 million liters, at a rate of 0.8 l/day/person for 6 million inhabitants.

This plant uses the Zimmerman process licensed from a Japanese firm. 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 method is a highly sophisticated one which requires skilled operators for controlling and maintaining the process. Although similar plants are in operation at present in Japan, this system has been used with little success in the United States (where it is known as the Zimpro Process). In most instances it remains problematical. The maintenance, repair, replacement, and the need for highly-skilled mechanical and electrical technicians create almost unending problems in keeping the system functional. The sludge that is created by the process is very hard to de-water and has no commercial value except as a soil conditioner. It has no utility for fertilizer.

Other methods for safe treatment and disposal were considered. Most employ storage and biological decomposition either under aerobic or anaerobic conditions, including one based upon 90 days of fermentation in a 5-meter deep tank followed by de-watering of the treated sludge. The water removed would be stabilized and chlorinated while the solids would be collected for use as fertilizer. This method is similar to present methods of disposal in pits, but it insures better destruction of pathogenic organisms. In Seoul it has been decided to postpone use of biological treatment until an adequate network of collector sewers has been built, the later phase of the two-phase treatment plan mentioned above. The Zimmerman plants will either be converted or moved to other locations or cities following their replacement.

The cost of transport of night soil converted to fertilizer after more thorough treatment is presently considered in excess of the benefits, although detailed studies have not been made. Anaerobic sludge digesters or composting were two other alternative methods suggested by Dr. Bowerman that would effectively sanitize the night soil and yield rich fertilizer. Working against the economies of the organic fertilizer product is the increasing use of chemical fertilizers, even though rural villages continue to compost human excreta for use in fields. A further obstacle is that alternative or presently used methods of treatment (excepting possibly the Zimmerman method) are not easily located. It has been difficult to find new disposal sites within 20 kilometers of Seoul principally because of objections by people living nearby. This is a common problem in all countries, including Japan, where an economic inducement was given to persuade people to accept night soil disposal sites near their homes.

5. Evaluation and Recommendations

As cities grow, the highest priority is usually to supply a quantity of water sufficient only to satisfy the basic bodily needs. Second priorities are for establishment of a safe supply. Finally, when per capita income rises to a sufficient level, people can afford to be concerned over amenities such as maintenance of clean streams and recreational areas. When a city begins to grow under conditions of low per capita income, concern for such amenities may seem a long time in the future. However, planning for the time when such a situation will come would appear the wisest course to follow. By realizing the cause and effect between water supply and wastewater production, and by establishing plans and procedures for meeting these conditions in the future, cities can develop in a less costly way.

The first concern should be with the development of a protected supply. Plans to make the supply more convenient, such as providing community taps, should be discouraged until one can be assured that the resulting increased demand can be satisfied. Extending supplies into the homes should also be discouraged until both an adequate supply to satisfy increased demand and an adequate method for disposal of the associated wastewaters can be assured. This could be done initially by the provision of drainage facilities from the houses to the drainage canals or to some type of interconnecting interceptor sewer or canal system to carry the wastes below the city or by the construction of minimal treatment facilities to prevent gross pollution of rivers and streams by the wastewaters which will result.

The problems which will result if such provision is not made can be seen in Seoul. The streets are narrow and passageways between houses are small. Construction of a sewage collection system of the usual type at this point would seem almost impossible without destroying significant portions of the residences which have been built.

Alternate schemes for collection, such as a vacuum system using small pipes not laid to grade, may offer a solution. However, such systems are new and untested to a large degree. The desirability of planning for the future handling of wastewaters is emphasized by the difficulty and expense in correcting inadequate sewage collection in areas with dense populations. In sites of future settlements, land rights-of-way can be acquired and a general plan for the eventual collection and disposal of waste can be developed.

Correction of deficiencies in existing collection and disposal systems can also be started. The development of the Chong Gye Chun treatment plant in Seoul is a good example of building a single portion of an eventual wastewater collection and treatment system. Treatment facilities are much less expensive than the collection system. As indicated earlier, a decision has been made to build a series of plants to treat the wastewater running from each of the major drainage basins of the city. A disadvantage of this system is that treatment is not 100 percent efficient; some portion of the wastewater will reach the river upstream from the water supply intakes. Partly because of this circumstance, the city will shift water intakes upstream to the Paldang Dam.

It would appear inevitable that the night soil method of human waste disposal will be eliminated once an adequate sewage collection and treatment system is established. Ordinances in Seoul are now requiring that in basins which are serviced by wastewater treatment facilities, human wastes are to be discharged to the sewer. Thus, a step in this direction is already being taken.

The downstream effects of industrial pollution from Seoul should be assessed, especially in terms of the adverse impact on the Han estuary and its biological resources. Since the estuary is shared by North Korea, concern for estuarine pollution is conditioned by political relationships. Since the industrial complex in Seoul has developed so that its wastes discharge downstream from the city, the importance of the pollution for the city is also lessened. Experiences elsewhere in the world indicate that special attention is needed to prevent contamination of productive estuaries and their fisheries resources. With this in mind pollutants in Seoul must eventually be assessed in terms of their downstream effects and therefore monitoring of estuarine pollution and biological impacts on fisheries and other important biota should begin.

It is necessary to improve the data base on water quality and pollution effects. A good start was made in monitoring water quality during 1972. Planners require the best possible data base and efforts to further develop water resources information should be continued and expanded.

More and better university training for public health engineers and training in water supply and pollution control is needed. A specific need is to determine the manpower and skill requirements for the construction and operation of the planned Zimmerman plants. The universities are not well supported for the training of graduates in these fields and their needs in this regard do not seem to be well understood by the public officials. Funds for research in this area at the universities are non-existent. There appear to be no serious research efforts by independent governmental laboratories. Again, funds seem to be lacking. Dependence on outside agencies for advice in water supply and pollution control is apparent. Such dependence may be necessary now, but is an unwise course to follow in the future. Such dependence could result in the establishment of inefficient systems to the extent that the city may not have the kinds of trained manpower needed to assess research needs and to evaluate the results of contracted research.

## E. SOLID WASTE*

In 1973, 7,000 tons of solid waste were being generated per day (Table 11), of which more than 60 percent consisted of anthracite briquet ash (Table 12). All of the ash is disposed of in landfills. The most serious problem recognized by city officials is that of sufficient disposal sites.

Table 11

Yearly Volume of Solid Waste Collected in Seoul 1967-1973

| Year | Tons | Rate of Increase (%) | Population |
|---|---|---|---|
| 1967 | 1,453,751 | 100.0 | 3,969,218 |
| 1968 | 1,903,884 | 131.0 | 4,334,973 |
| 1969 | 2,000,645 | 137.6 | 4,776,928 |
| 1970 | 2,128,194 | 146.4 | 5,536,377 |
| 1971 | 2,384,426 | 164.0 | 5,850,925 |
| 1972 | 2,514,808 | 173.0 | 6,076,143 |
| 1973 | 2,705,100 | 186.1 | 6,300,000 (Est.) |

Source: Bureau of Environment, Metropolitan Government of Seoul, 1973.

Outside of a certain amount of water pollution at waste disposal sites, the management of solid wastes in Seoul was

*Originally authored by Dr. Frank R. Bowerman (see Preface).

Table 12

Composition of Seoul Solid Wastes, 1971, With Comparative Figures for Two Japanese Cities

| | | Composition in Percent | | |
|---|---|---|---|---|
| | | | Japan | |
| Nature | Type | Seoul[(a)] | Tokyo (1969) | Na Go Ya |
| Combustible | Paper | 9.0 | 33.3 | 37.0 |
| | Plastics | 3.0 | 9.7 | 12.3 |
| | Garbage | 10.0 | 31.8 | 18.0 |
| | Fiber | 4.6 | 3.6 | 4.0 |
| | Wood | - | 1.6 | 3.5 |
| | Others | - | 7.5 | 0.2 |
| | Total Combustible | 26.6 | 87.5 | 75.0 |
| Incombustible | Glass and China | 1.7 | 5.0 | 11.0 |
| | Metal | 2.9 | 2.9 | 5.5 |
| | Soil | 7.0 | 4.6 | 8.5 |
| | Anthracite Ash | 61.8 | - | - |
| | Total Incombustible | 73.4 | 12.5 | 25.0 |

Source: Bureau of Environment, Metropolitan Government of Seoul.

(a) Average of four samples taken in winter, spring, summer and fall, 1971.

observed to be non-polluting, effective, and conserving of recyclable materials. In Seoul, the solid waste management system is greatly dependent upon human labor and less upon machines to a degree that would not be economically feasible in the United States.

The organized system of solid waste collection performed by employees of the City of Seoul appears to have reasonable efficiencies and compares not too unfavorably with door-to-door and commercial collections practiced throughout most of the developed nations. The equipment is similar to that found in many municipal systems in the U.S.A.

The solid wastes collected from homes, apartments, commercial business, or industries are taken to several "sanitary landfills" and deposited for disposal. Almost before the material being dumped has had a chance to reach the ground, it is picked over by men and women--some equipped with pitch forks--and all useable materials are quickly extracted from the dumped load before it is left for burial. Extracted materials include bits of plastics, pieces of wood, (even down to matchstick size, apparently for fuel), rags and bits of cloth, paper, paper products and almost anything that has value for heating purposes. Almost no tin cans or bottles appear within the dumped loads.

There are probably health problems associated with the manner in which solid wastes are salvaged at landfills, but the primary problem is that landfills are situated in or adjacent to stream channels and lead to water pollution. Dr. Bowerman observed in 1972 that there was virtually no attempt to cover the solid wastes at one landfill, although at another site bulldozers were in evidence and some earth was being placed on the top of the refuse (apparently at the level where the landfill was considered to be complete). In order for a landfill to be "sanitary" in the United States, it must be covered daily with earth to prevent flies, rats, and the blowing about of paper. In Seoul the material left for disposal doesn't contain much that blows around or burns so the problem is less important than in the United States.

Cans and bottles do not find their way into the solid waste collection. They are almost entirely scavenged by itinerant "junk men" who travel the city streets from early morning until late at night with hand-drawn, two-wheeled carts. These men are characterized by a large plastic bag of popcorn being carried in the cart and a pair of sheet metal "scissors" that they continually clang together to alert the neighborhood as they travel the city streets. Persons of all ages (but principally children) bring articles of apparent value, such as tin cans and bottles and cloth, leather, plastics, etc., to the popcorn man where the wastes are traded for a handful or two of the popcorn depending on the particular value of the goods received.

This system is highly effective in saving the metal from the cans, or saving cans as containers, and returning glass bottles as refillable containers. It is totally dependent on a cheap labor market and would not be a characteristic of any country that could offer better employment. The popcorn men appear to be well organized. They obtain their popcorn at several centers where it is popped in the early morning hours for distribution. The men return that evening with the collected goods. One such area, whose name in English is roughly "Salvage Street", is a series of crude structures, each one representing the salvage of a different form of waste, such as tin cans, bottles, bones, plastics, paper, rags, etc.

Considering the effective and the efficient manner in which Seoul is recycling useful solid wastes, there is little that could be recommended in the way of alternative disposal systems such as incineration, pyrolysis, composting, or centralized separation for salvage. The utility of such systems would be virtually nil because of the high degree of separation and salvage of useable materials already practiced and the relatively low utility of the residues that are left at the landfills after they have been picked over by scavengers at the site. These observations will be outdated as the technological level of the Korean economy progresses and the standard of living increases. However, for the near future no changes are recommended in the current methods of solid waste collection in Seoul.

The increasing scarcity of suitable sites for disposing of close to two million tons per year of anthracite briquet ash, is, however, of concern to the city government. Experiments to find uses for the ash as construction materials have not been fruitful and this alternative is not technically feasible at this time. A survey of future possible fill sites is needed to establish a basis for planning disposal. A final consideration is that this disposal problem will be directly affected by fuel policy for home heating in Seoul, for in the near future the discontinuation of the use of anthracite briquets is not anticipated. However, a shift to natural gas, now unlikely in the energy crisis, would greatly alleviate the situation.

## F. AIR POLLUTION*

### 1. Introduction

It would be surprising if there were no air pollution problem in Seoul, in view of its population of slightly more than 6.0 million and the climatic and topographic conditions that create temperature inversions. It is not as severe, however, as would be expected for a city of this size, partly owing to the relatively few vehicles in the city. Neither is the pollution as serious as some earlier data indicate, owing to their inaccuracies. Nevertheless, it is sufficiently acute that there are unquestionably a few very bad days during the winter and that the long-term effects are detrimental to health.

Until 1973 there were relatively few air quality data for Seoul, very few are available for Pusan and Taegu, and none exist for other cities. Inchon appears to have the potential for very severe pollution from a large steel mill and there have been reports of pollution damage to orchards outside of Seoul from various industries. The problems of obtaining good data on air quality, and of assessing the significance of the data, are indicative of monitoring and assessment problems which will arise in other major cities and industrial sites in the Republic of Korea.

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*Originally authored by Dr. James P. Lodge (see Preface).

## 2. Pollutant Monitoring and Concentrations in Seoul

Sulfur oxidants and dustfall have been measured every two months by the City since 1969 at a number of stations. Beginning in September, 1973, sulfur dioxide and carbon monoxide are being monitored with new instrumentation. The city also regulates emissions from the approximately 4,300 industries in Seoul subject to air pollution regulations. In addition, the National Institute of Health operates a mobile unit equipped with Beckman instruments which conducts continuous monitoring in Seoul of $SO_2$, CO, $NO_x$, hydrocarbons, and particulate matter. Improvements in both instrumentation and analytical methods are enabling a more accurate measurement of both ambient air quality and emissions. However, differences in methods and instruments used make it difficult to compare data so as to analyze trends. Good baseline data on air quality in Seoul will probably not be available until the end of 1974 or 1975. Nevertheless, existing data do enable a general characterization of Seoul's ambient air quality.

Ambient concentrations of sulfur dioxide and dustfall have been measured from 1969 to 1972 in four land-use zones in the city: industrial, commercial, residential and green space (Table 13 and 14). The location of the 25 existing stations is shown in Figure 4.

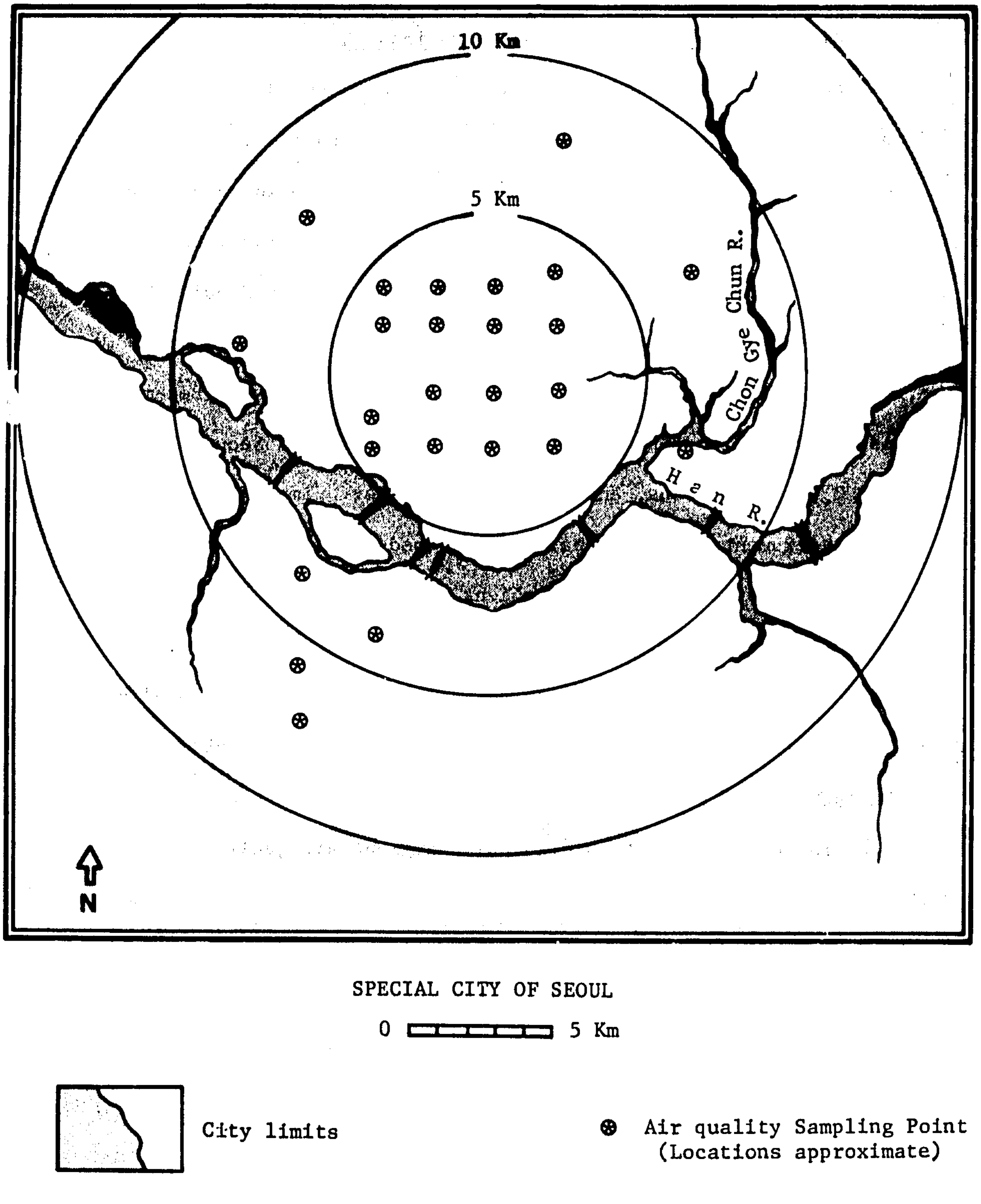


Figure 4. Air Pollution Monitoring Stations, 1973.

Table 13

Ambient $SO_2$ Concentrations, Seoul, 1969-1972
(in ppm)*

| | 1969 | 1970 | 1971 | 1972 |
|---|---|---|---|---|
| Industrial | 0.052 | 0.061 | 0.068 | 0.067 |
| Commercial | 0.049 | 0.054 | 0.063 | 0.062 |
| Residential | 0.041 | 0.047 | 0.046 | 0.049 |
| Green Space | 0.027 | 0.029 | 0.028 | 0.029 |

*Lead Peroxide Candle method

Table 14

Dustfall in Seoul, 1969-1972
(in metric tons/month/$km^2$)*

| | 1969 | 1970 | 1971 | 1972 |
|---|---|---|---|---|
| Industrial | 25.1 | 31.1 | 34.9 | 32.5 |
| Commercial | 29.0 | 30.6 | 34.4 | 31.2 |
| Residential | 20.7 | 18.4 | 20.3 | 18.3 |
| Green Space | 11.8 | 14.3 | 17.1 | 12.8 |

*British Standard Deposit Gauge method

Dustfall is measured by a copy of the British "Standard Deposit Gauge," and figures obtained are consistent with what would be expected of a typical city. The "Lead Peroxide Candle" method is used to measure $SO_2$. This technique has the advantage of simplicity, but the disadvantage that it cannot be directly related to $SO_2$ concentrations in the air. The NIH mobile laboratory measures $SO_2$ by the electrical conductivity method, and results have differed from city data by 50 percent. The city has also experimented with the West and Gake method for $SO_2$ analysis, which yielded results closer to the mobile lab findings than to the Lead Peroxide Candle analyses.

Other specific pollutants have been measured in Seoul. Data obtained for the period July to November, 1970, are reported by Cha (1971) and are summarized below.

| | |
|---|---|
| Total dustfall | 33.2 m.t./km$^2$/month |
| Suspended dust | 3.14 mg/m$^3$ |
| Sulfation | 1.64 mg/day/100 cm$^2$ |
| $SO_2$ | 0.092 ppm (daily mean) |
| CO | 33.4 ppm (daily mean) |

Total dustfall is consistent with data collected by the city, but suspended dust seems to be excessive by a factor of 10, since it would correspond to a mean visibility of not much more than one city block over the entire city for the entire period. Recent measurements of suspended dust made by the city with a high volume sampler yielded 540 to 720 micrograms per cubic meter, as opposed to 3,140 micrograms reported by Cha. The probable explanation of the difference is that in the past all measurements have been made with a single instrument, a Japanese-built "Digital

Dust Indicator." It is a 45-degree light-scattering particle counter. This draws a very fine stream of sampled air through an intense light beam. A photocell picks up the flash of light as each dust particle passes and these are counted. If the size distribution of the particles is fixed, the number concentration can be simply transformed into a mass concentration. However, if size is variable, as it is likely to be, this transformation is impossible. But a single conversion factor was used with the result that these figures are high by a factor estimated at 10 to 20. They are really almost useless, although the trends have some meaning in that they reflect changes in number concentration.

Sulfation rate, a not very accurate index of sulfur dioxide content, is also not atypical. It suggests a serious $SO_2$ problem, but not a crisis. The daily mean $SO_2$ concentration reported by Cha was obtained by the "indicator tube method," which is poor at these concentrations; it was intended for the much higher levels found inside industrial plants. The figure of 0.092 ppm is about twice that measured by the City of Seoul, and city technicians believe that Cha's figures are too high.

Carbon monoxide data seem a bit high, but may be correct. The indicator tube method was used. The concentrations are high enough to be within the range of air accuracy for the method; accuracy is probably $\pm$ 30 percent.

The CO figures are consistent with data obtained verbally at the National Institute of Health for nitrogen dioxide of about 0.2 ppm, apparently obtained by the Jacobs-Hochheiser method. These $NO_2$ measurements were made in late 1968. There is a trick in calculating data using that technique and it is not clear whether or not the analysts were aware of this. The systematic error introduced is only about 30 percent, but might be in either direction. It is most probable that the figure is low. The precision of the method itself is probably about 20 percent. The mean has doubtless increased in the past three years.

Variation of all pollutants from one area of the city to another is in the expected sense. Dustfall, for example, is highest downtown and lowest in residential areas. Suspended dust varies in the same sense. Not surprisingly, CO is higher downtown than in an industrial area. Less conventionally, the same was true of $SO_2$. Both show morning and evening maxima, with the latter the larger.

### 3. Meteorological Data

In the last three years, some seventy additional meteorological stations have been installed in Korea; there are three radiosonde stations. This is something on the order of a 250 percent increase in data gathering capacity during this period. The Central Meteorological Office has weather radar and APT equipment. Archived data are being placed on microfiche with provision for encoding by some sort of criteria and automatic sorting. Staff seem to know their jobs. Some interesting research is in progress on evaporation control for rice paddies.

A major ingredient in the Seoul air pollution problem is the extremely seasonal rainfall. Seoul receives a nominally ample total annual rainfall of about 170 cm. that falls between June and October. The balance of the year is dry. Temperature inversions are common in the late fall and winter. The mountains and the Han River valley doubtless make for very complex air circulation patterns. There is a sort of saddle between Nam San (South Mountain) and the general range to the west, and it appears that much haze stays south of that saddle.

Using existing, limited meteorological information and the results of $SO_x$ and dustfall measurements for 1969-1971, Mr. Hosang Kim, of Seoul National University, undertook a statistical analysis of the effects of weather on these two pollutants in Seoul (Kim, 1973). High concentrations of sulfur oxides, especially in the southwest industrial area, correlated with periods of high atmospheric pressure and clear skies, especially in the winter. These could well be periods of temperature inversions. On the other hand, dustfalls were greatest in summer months with high atmospheric pressure, high temperatures, and wind speeds in excess of 2.7 m/second. This latter finding supports the conclusion that the origin of dust is largely from unpaved roads and areas cleared of vegetation, which under such weather conditions would be dry and susceptible to wind erosion. Correlation analysis by computer indicated that pollutant concentrations were greatly influenced by weather conditions; 49 percent of the $SO_x$ and 45 percent of the dustfall was directly related to weather factors.

The scant amount of meteorological and micrometeorological information available for Seoul greatly hampers predictive and assessment capabilities in air pollution work. Funds have not been available for the needed surveys and data collection; however, the Director of the Central Meteorological Office has proposed to the UNDP Special Fund the financing of a Meteorological Research and Training Institute. Such interim techniques as low-altitude aerial photography, lapse time cinematography from a mountain top or TV tower, and the installation of a cheap thermograph on the cablecar which runs up the north side of Mt. Nam San would be useful. The city plans to install a continuous, automatic-recording meteorological station on the TV antenna on Mt. Nam San.

4. Effects of Pollution

Very few effects studies have been made and those available are not definitive. No observations on plants or animals have been made; however, assessments of human health impacts have been attempted. A survey reported by Dr. Lee Hyo-Jae (1971) stated that during October, 1966, 35 percent of the population had a respiratory disease at any given time. Dr. Cha Chul-Hwan of Seoul National University expressed his unqualified opinion that air pollution is an important cause of illness in Seoul. An abstract of a published paper by Cha showed a higher incidence of illness, by a factor of about 1.5, in Seoul than in the much smaller city of Suwon. The highest factor came from hillside areas, which tend to be squatter settlements. The City's Bureau of Environment believes that the important condition in these areas affecting incidence of respiratory disease is the temperature gradient, which shows large differences in these hill areas. Other factors noted by Cha are not seriously inconsistent with air pollution as a contributing factor, especially as the survey was taken during the winter of 1970-71.

Dr. Lodge observed air pollution and/or haze which restricted visibility to perhaps 5 to 10 kilometers and the soiling of buildings. There was no noticeable excessive attack on statuary, but of course nearly all monuments in Korea are relatively recent--i.e., since 1945. During his trip to Inchon, at no point did Dr. Lodge observe any striking improvement in visibility. Clearly, some significant fraction of the airborne particulate matter is natural or comes from sources in China. The previously cited paper on pollutants in Seoul by Cha, _et al_. (1971), reveals that the dustfall is about one-third water soluble, which is in line with a substantial natural component.

5. Sources of Pollutants and Regulations

Very little data have been compiled on pollution sources. Under a newly effective city air pollution ordinance, the Seoul Metropolitan Government has registered 4,300 industries which are subject to emission regulations.

Until 1972, there was no requirement for control of pollutants. An earlier law, passed in November, 1963, and amended in 1971, became effective January, 1972, which set a limit of Ringelmann 2 (40 percent black) on smoke shade with 6 minutes out of any hour in the winter and 4 minutes in the summer allowed for firing, soot blowing, etc., with no limit during that period. In addition, emission and ambient standards were set for a number of pollutants (Table 15). Ambient standards specify maximum concentrations that can occur outside the property line of the emitter. Fines of up to W 2,000,000 ($50,000) and prison sentences up to two years can be levied against the responsible individual in some kinds of violations. The basic laws concerning emission pollution control appear to be sound.

Some training in the use of the Ringelmann chart is apparently provided by the National Institute of Health. In the absence of any source testing program, excessive smoke is probably the only

Table 15

1972 Legal Limits to Emissions and to Pollutants at Ground Level, Under Korean and Seoul City Regulations

| Substance | Ambient Limit at Plant Boundary | Emission Limit |
|---|---|---|
| Ammonia, $NH_3$ | 40. ppm | 600 ppm |
| Carbon monoxide, CO | 40. ppm | 3,000 ppm |
| Hydrogen Chloride, HCl | 2. ppm | 60 ppm |
| Chlcrine, Cl | 0.5 ppm | 50 ppm |
| Sulfur oxides, $SO_x$ | 1.5 ppm | 3,000 ppm |
| Nitrogen oxides, $NO_x$ | 1.5 ppm | 250 ppm |
| Carbon disulfide, $CS_2$ | 7.0 ppm | 120 ppm |
| Fluoride, F | 1.0 ppm | 10 ppm |
| Formaldehyde, $CH_2O$ | 2.0 ppm | 70 ppm |
| Hydrogensulfide, $H_2S$ | 4. ppm | 150 ppm |
| Arsenic, As | 0.03 ppm | |
| Benzene, $C_6H_6$ | 15. ppm | |
| Phenol, $C_6H_5OH$ | 4. ppm | |
| Chromium, Cr | 0.05 $mg/m^3$ | |
| Cyanide, CN | 2. $mg/m^3$ | |
| Phosphate, $PO_4$ | 0.4 $mg/m^3$ | |
| Dust | 10. $mg/m^3$ | 2 $g/m^3$ |
| Soot | 25 mg/hr or 50 $mg/m^3$ | 1.2 $g/m^3$ |

Source: Adapted from standards set by the Americal Conference of Industrial Hygienists. Set in 1963 with the passage of the Law on Public Nuisance offense that will be prosecuted for several years. The standards are used primarily in the design of new facilities. Universities and private industry are collaborating with the government in the design of pollution control equipment.

Industrial air as well as water pollution have been monitored to a degree since 1972. This is the responsibility of the Environmental Control and Administration Section of the Bureau of Environment. That section has a staff of approximately 55, of whom 13 are laboratory technicians. An emission inventory was initiated in 1972 by various branches of the Bureau of Environment and was scheduled for completion at the end of 1973. Information from this survey should be very helpful in better understanding existing emission loads on ambient air quality as well as in planning the enforcement of standards.

Many of the permissible industrial emissions seem to reflect utter disregard for life and limb. The fluoride level permitted is astonishingly high. Fluoride standards should be nearer one part per billion. Dr. Lodge noted very large discharges from the glass industry, however, most of these are located outside of the city boundary. A discharge that produced 1 ppm of soluble fluoride at the plant fence would kill many varieties of vegetation for some miles downwind and make surviving vegetation dangerous to man or beast. In fact, some damage to orchards has already been sustained. No attention is paid to cattle fluorosis, much less the typical leaf tip necrosis in pine, gladiolus, and the rose family, but it is probably evident.

While industrial emissions are difficult to estimate, and their assessment must wait for the results of the emission inventory, pollutant loading from fuel combustion has been calculated. A paper by Chae Il-Suk (1969), a student of both Dr. Cha and Dr. Kwon, computed emissions for all of Korea from heating and similar energy conversion processes. A set of emission factors were given which appear to have been adjusted for the particular conditions of Korea. More recently, the City's Bureau of Environment made a similar computation, the results of which are shown in Table 16. The attempts are roughly comparable, except that larger amounts of pollutants in the more recent computation reflects increased quantities of various fuels burned.

It is clear that domestic heating is the overwhelming source of air pollution in all categories except hydrocarbons, over 70 percent of which come from transportation sources. Hydrocarbons and nitrogen oxides would be present in sufficient concentrations to cause "Los Angeles-type" photochemical smog during the summer, and reports suggest that this is true. However, no measurements have been made of any ingredients except nitrogen dioxide, which is not very diagnostic.

Table 16

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 | 2,355 | 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.

Industry and electrical power plants use heavy petroleum oils, predominantly Bunker-C. Korean petroleum products are all made from Near East crudes of high sulfur content, so Bunker-C oil as used here contains about 4 percent sulfur. Power plants do not produce much observable smoke and, of course, ash is not a serious problem. However, the major downtown buildings are heated by heavy oils as well and produce heavy smoke during startup.

Diesel fuel, like much similar oil sold in Mexico, contains about 2 percent sulfur. Diesel engines in Korea are operated almost universally at full load or above. A large city bus might well have a 100-150 horsepower engine. Most diesel vehicles are old, maintenance occurs only when they do not operate, and there is a great tendency to employ used, rather than new, replacement parts.

The average day's travel for an auto in Seoul is something over 200 km. Hence, these vehicles travel an average on the order of 50,000 miles per year, nearly all of it within the city. The average traffic volume is thus equivalent to some 10 times as many automobiles as were registered (67,000 in 1973).

With such large mileage autos age rapidly, but do not retire. As with the diesel vehicles, repairs are made only when essential, and then usually with used parts. Vehicle emissions are high and are made still higher by driving habits, which maximize those parts of the operating cycle giving the highest emissions. Probably the respective time percentages would be 20 percent hot idle, 40 percent acceleration, 40 percent deceleration and almost no cold idle or cruise. Smoother traffic flow would improve the situation. Pedestrians operate by rules that are unique and cause a lot of abrupt stops by vehicles.

There is a law that a vehicle which emits smoke in excess of Ringelmann 3 must be removed from the road and that Ringelmann 2 elicits a notice to repair. It is not clear whether this is enforced. The law also requires that carbon monoxide emissions be tested as part of the six-month safety inspection, the limit being 5.5 percent CO in the exhaust. However, no facilities exist for such tests. Actual testing is perhaps two years off at best; KIST was reviewing testing procedure alternatives.

Consumption of petroleum other than by cars and buses (jet aircraft, etc.) is negligible, as is use of bituminous coal.

Korean anthracite is low in sulfur, but very high in ash content. Nearly all of it is used in home heating and cooking using the unique ondol system. In a typical Korean home, 2 or 3 rooms are so heated. The kitchen is excavated below ground level, and is also the "furnace room." The interior kitchen walls have 3 to 5 openings, 1 or 2 into the space under the floors in each of the _ondol_ rooms. Heat and combustion gases from fires stoked in the kitchen are led through these openings to heat the floors, finally reach a chimney. The fuel was originally wood, but is now, except in extremely rural areas, anthracite briquets.

The _ondol_ is an extremely comfortable system of radiant heating, well adapted to the bitter Korean winter climate. But there are several problems. One is that the combustion of one 4.4 kg anthracite briquet leaves a residue of 1.8 kg of ash to dispose of. Each _ondol_ requires about 2 briquets per day, or 6 to 10 per typical house.

Total anthracite consumption in Seoul last year was over 5 million metric tons. Consumption for purposes other than home heating is negligible. This leads to the interesting consequence that Seoul, with a mean annual per capita income of around $200, generates 350 kg of solid waste per person per year. Seoul's solid waste production is comparable with that of a typical, fairly affluent European city. Incineration is of little help, since most of this is incombustible ash. This ash is also probably an important ingredient in dustfall.

A second consequence is indoor carbon monoxide poisoning. When the air vents at the bottom of the pot are partially closed, the burning anthracite becomes a very efficient generator of CO. If there is any imperfection in the sealing of the ducts, or if the chimneys fail to draw, CO often enters the house in a high concentration. The standards of wall construction are not high. For example, most chimneys have no liners, one side being the wall of the room. Koreans who are aware of the danger spend much time after moving into a new house painting the walls, calking the door jambs, and the like. Some install flue liners. However, in the event of a real malfunction, this is self-defeating because the potential for CO build-up is greater when the ventilation rate is lowered to as little as 1 to 2 changes of air per hour. Reportedly, there were 500 deaths in Seoul in the winter of 1972 from this cause. (Some were deliberate; tampering with the <u>ondol</u> reportedly is a favorite form of suicide.) There are few data of consequence on the prevalence of sublethal effects and none on the subclinical consequences of this sort of carbon monoxide exposure.

The 20 plus factories in Seoul that produce anthracite briquets represent another source of pollution associated with this technique of heating. The anthracite coal is ground into a fine dust, mixed with a small amount of clay (less than one percent by weight) and shaped by machine into round briquets. The interiors of these plants are extremely dusty, constituting a respiratory hazard for workers, and the factories also emit a certain amount of dust into the ambient air. The need for better control of dust from these factories is recognized by city officials. Recently, dust collectors have been installed on the chimneys of most of these plants. Also the plants reportedly intend to plant trees in their vicinity to capture some of the dust.

6. Research and Development Needs

There are two fundamental types of information which must be obtained as soon as possible, at least within the next two to three years. The first is adequate qualitative and quantitative information on the nature of air pollution in Seoul. This calls for a sustained monitoring effort which has been started by the Institute of Hygiene, Bureau of Environment. To permit non-routine studies of pollutants that cannot be continuously monitored, it is suggested that support be provided to each of the major research laboratories--the groups interested in air pollution at Yonsei University, Seoul National University, etc. Each will require a carefully selected assortment of specialized equipment. Procurement should be reviewed prior to order on two grounds: 1) no duplication, each group selecting its own area and adhering to it; 2) an experienced air chemist should be consulted to assure the equipment will actually perform as specified. If possible the apparatus should have other capabilities as well. For example, there is a specialized commercial instrument that will measure peroxyacetyl nitrate, an ingredient in photochemical smog. For slight additional cost, another instrument can be purchased that will also measure chlorinated hydrocarbon pesticides and a number of other environmental contaminants. Furthermore, since it is extremely difficult to procure spare parts or have instruments serviced in developing countries, it will pay in the long run to insist on high quality equipment.

Secondly, data are needed on the micrometeorology of the Seoul air basin. The logical agency to obtain this information is the Central Meteorological Office, with assistance from the Institute of Meteorological Research and Training when it is established. Three early and relatively inexpensive steps can be initiated: 1) A photographic observation site can be sought on a mountain top which commands a view of a good portion of Seoul and is much of the time above the local haze layer. Lapse-time cinematography can trace the diurnal movement patterns of the pollution, as well as some significant sources that might otherwise be missed. 2) If it is possible under Korean law, systematic, low-altitude (700-100 m.) aerial photography on high-pollution days will also show the movement of the cloud of pollution. The aircraft should fly a pattern over the city that can be repeated at intervals of thirty minutes to one hour from first full daylight until inversion breakup. 3) Use should be made of the presence of Mt. Nam San, in the center of the city. The cable-car can be equipped with a simple (W 50,000) temperature recorder.

Its travels up and down the hill will give "vertical" profiles of temperature at very low cost. At slightly greater cost, readings may be extended in the vertical by installing temperature recording equipment on one of the television masts atop Mt. Nam San.

For the longer term, presently planned work at the Korean Institute of Science and Technology to develop means of testing automobiles for CO emssions and to evaluate simple devices to improve carburetion should be encouraged. If a solution to the <u>ondol</u> problem is really desired, the present prize of W 10,000,000 ($25,000) should be better publicized both within and outside Korea. Possible practical uses of briquet ashes also could be further studied.

A competent and interested scientific administrator must be given responsibility for coordinating research on air pollution throughout Korea. Because of scarce resources, only limited duplication (or competition) should be tolerated. There is already some sharing of monitoring equipment. This practice is commendable and should be extended.

Every effort must be made to upgrade personnel at all levels in air pollution research, especially in control activities. Sending technical staff abroad for specialized training would be a good beginning. Training is needed for key personnel of the enforcement staff. Once trained they need to be paid enough to prevent them from resigning for better-paying jobs or from being tempted to accept payments aimed at reducing enforcement efforts. Industries should be urged to assign key engineers to counterpart industries in countries where controls are strict or, in the case of foreign firms, to bring in experts to provide training to local staffs.

7. Control Recommendations

Several purely practical steps can be taken immediately to strengthen pollution control.

Industries generally can be persuaded to "tighten up" their operations. Many Korean industrial plants do not emit pollutants only from their chimneys, but from every chink in the building, every exposed valve, every ventilator, and every door. If these pollutants are simply better confined and exhausted to the stack to the maximum extent possible, surface pollutant concentrations near the plant would drop sharply.

This could easily be coupled with another step. There are numerous techniques for computing necessary chimney heights, given emission concentration, chimney exit temperature, and desired maximum ground concentration. The British have developed a very simple nomogram for the purpose. Better confinement and higher chimneys do not reduce pollutant mass discharged, but they do make possible much more restrictive and healthy ambient standards than those presently in force.

If ambient fluoride levels actually reach 1.0 ppm, they would be intolerably dangerous. A simple loose bed of coarse limestone would reduce hydrogen fluoride to safe concentrations. A schedule would need to be worked out and enforced for replacement of spent limestone. If hydrofluoric acid must be imported, or is produced locally from imported fluorspar, it might be worthwhile to reprocess the resulting calcium fluoride. Refinery waste gases should be flared.

Finally, despite all the previous comments concerning the lack of meteorological data for Seoul, there <u>are</u> surface wind data. These can be used, in consultation with the Central Meteorological Office, for planning future plant locations. The recent study of Denver by Herbert Riehl and Loren W. Crow (1970) could serve as a model. Some areas probably should be totally closed to new industry and some current industrial firms encouraged to relocate elsewhere.

The transportation sector will yield far more slowly. One policy that could be adopted immediately is to require trucks and buses to install exhaust pipes extending above the vehicle. Like the tall factory chimney, this would not decrease pollution, but it would improve dispersion.

Over a longer time scale, the total concentration from transportation can be decreased markedly by simply smoothing traffic flow. This means devising techniques, for example, to inhibit "cowboy" driving. Other steps might be synchronized traffic lights, through bus lanes on streets wide enough for them, better control of pedestrians, and adopting all means possible to discourage growth in the number of vehicle-miles driven in the city. The subway should certainly help in this regard.

Meaningful vehicle inspection and enforcement of vehicular smoke regulation are both valid actions, but could prove unpopular or unworkable because of the high cost of repairs that will be required to overcome the problem. It might be better to require improved performance in new cars, allowing replacement to do the job. All Korean auto makers are affiliates of foreign companies that sell in the U.S. market and possess the know-how to produce less-polluting autos. An added first cost is likely to be more acceptable than expenses for a major engine overhaul enforced by an agency of the government. It is also possible to oblige makers of new trucks and buses to install larger engines; the lighter the load on a diesel engine, the less it smokes.

Still further in the future, desulfurization of diesel fuel would be desirable. It would be worthwhile to study the experience in Mexico City which experienced a similar problem. The added fuel cost possibly would be offset to an acceptable degree by extended engine life.

The heating of major buildings by Bunker-C fuel oil (or coal, for that matter) is presently accompanied by an unacceptable amount of black smoke. Training of firemen to identify offenders and then empowered to issue citations to owners for smoke violations, accompanied by suitable publicity, could help considerably.

Because of the many factors inherent in the use of the _ondol_, many of which have nothing to do with air pollution, recommendations are conditional. Upgrading housing to decrease the number of old style _ondol_ systems will decrease the acute indoor problem. Flue liners in chimneys should be required, but this is difficult to enforce. A new building code, building inspectors and a building permit system would have a salutory effect on this problem. Flue liners could improve the draft as well as decreasing leakage; better dispersion will again result.

Finally, the nuisance dust (dustfall) problem can be ameliorated by paving streets, planting trees along major streets (or not removing them), and particularly through a major effort to stabilize disturbed soil. The practice of bulldozing an entire building area bare is lamentable, but perhaps is excusable in view of the severe housing shortage. There is a notable lack of any reseeding, tree planting, or any practice that would hold the disturbed earth in place. Present rates of denudation and wind and water erosion have already closed most of the Han River to navigation. If the practice is not reversed, most of the country could be turned into a desert in several generations.

As previously mentioned, some of the dust consists of briquet ash. The best solution is to find a practical use for the ash.

8. Miscellaneous Recommendations

More and better technical literature on pollution should be provided. There are no good collections of Western books and journals on pollution, especially the more technical ones. Although many workers are familiar with the rather poor World Health Organization monograph, only few interviewed by Dr. Lodge knew the three-volume treatise by Stern, *Air Pollution* (1968). Several major workers in air pollution apparently never see journals dealing with air pollution such as *Environmental Science and Technology*, *Journal of the Air Pollution Control Association*, *Atmospheric Environment*, or *Staub*. The USIS library in Seoul subscribes to a few pollution publications, but only the U.S. ones. An arrangement should be devised which takes into account the high cost of this literature. Stern's treatise costs about $130 in the U.S.; an institutional subscription to *Atmospheric Environment* costs $65.00/year.

Despite hazards of creating still another organization, consideration should be given to forming a Korean Air Pollution

Association. Meetings would provide a specialized channel for information exchange, and membership in the International Union of such societies would allow a few members to attend worldwide conferences and confer with counterparts from other countries. In addition, sponsorship should be sought for a periodic review of programs by knowledgeable but sympathetic outsiders. The intent should be advisory with a clear implication of the fallibility of short-term experts from out of town. Generating material for these purposes could be a function of the Air Pollution Association.

## G. PESTS AND PEST CONTROL*

### 1. Introduction

The more significant insect and rodent pests affecting Seoul's urban population occur at the interface between rural and urban conditions. While urbanization reduces the proportion of the population exposed to insect vectors, such as the malarial mosquito, land-use changes leading to bad drainage at the edge of Seoul provide good habitats for mosquitoes including the vector of Japanese encephalitis.

The movement of large segments of the Korean people from rather isolated rural areas to major population centers will, inevitably, eliminate the natural barriers that have tended to keep some diseases within rather clearly defined geographical limits of the country. Individuals infected with malaria or filariasis, diseases now confined to some of the more remote areas of southern Korea, could move to Seoul or other major urban areas. Since suitable vectors for each of these are plentiful in most of the cities, the individuals in Seoul could serve as infection sources for local outbreaks of these diseases. Similarly, rapid air travel from many areas of the world now make it conceivable that infected individuals could travel to Seoul before the clinical onset of a disease, if

*Originally authored by Drs. Kyle R. Barbehenn and Harold D. Newson (see Preface).

suitable arthropod vectors there could initiate disease outbreaks in this populous area.

Increasing use of insecticides in rural areas to control the rice stem borer may be also controlling mosquito vectors. Reduction in mosquito vector populations following insecticide use have not yet been noticed, however. Pressures are being exerted on these as well as crop pest populations to develop insecticide resistance. Important agricultural production and public health problems are associated with the increasing use of chemical pesticides.

2. Mosquito-borne Diseases

a) Japanese Encephalitis. This is a very severe virus disease transmitted by a mosquito, *Culex tritaeniorhynchus*, that breeds primarily in relatively fresh water such as occurs in rice paddies and fresh water swamps. In rural Korea, pigs are intermediate or alternate hosts for the encephalitis virus, to which they can develop resistance.

Repeated epidemics of this disease have occurred in Korea with a fatality rate of approximately 30 percent and marked sequalae in about 50 percent of the survivors (Ministry of Health and Social Affairs, 1969a). The mosquito vector apparently overwinters in the adult stage, is present in the very low numbers in late spring, increases during the rainy season from May through July, and reaches population peaks during mid-August, coinciding with the peak incidence of the disease in humans.

Following a major epidemic in 1949, in which there were over 5,600 reported cases throughout Korea with over 2,700 deaths, (Ministry of Health and Social Affairs, 1969a), epidemics occurred in 3-year cycles through 1958. Since then, the 3-year epidemic cycle has not occurred, but the disease persisted at or near epidemic levels in most subsequent years until 1969, when there was a precipitous drop in the number of reported cases. As of 1972, Korean and WHO researchers had not yet been able to determine if there had been a corresponding decline in disease incidence. Data for Seoul on the incidence of Japanese encephalitis had not yet been collected. Historically, this has been a rural disease and clinical cases have been seen primarily in Korean children (especially susceptible are 3 to 5 year olds), rather than adults. A limited immunization program has been conducted in rural areas of the country during the past six years (Park and Kim, 1971). Approximately 50,000 of the 9.0 million total children have been immunized during this period.

It is the impression of both the Korean Government Health Ministry and the World Health Organization Japanese Encephalitis Vector Research Unit (WHOJEVRU) in Seoul that there are changes occurring in the epidemiological aspects of this disease. These changes could be very significant. Field studies by WHOJEVRU have shown that mosquito vectors now are much more numerous in suburban than in rural areas, and convey the impression, yet to be definitely substantiated, that human infections with this virus are becoming more common in urban-suburban localities than in rural areas (Lee, et al., 1971, and Self, et al., 1971). At the same time, a sharp increase in vector populations has occurred in unfarmed paddies and swamps located in many urban-suburban areas now being developed for building and industrial sites. A number of areas of this type were seen in Yongdungpo-Ku, Dongdaemun-Ku, and Songpuk-Ku. Most of these sites are among or immediately adjacent to slums or concentrations of squatter dwellings that provide minimal protection from mosquitoes. The Japanese encephalitis immunization program in the Seoul area is minimal at this time. Consequently, there are large susceptible segments of the population of the metropolitan area living in areas where outbreaks of Japanese encephalitis are quite likely to occur. The potential for future disease outbreaks in these areas should not be minimized.

Levels of insecticide resistance that have developed in the *Culex tritaeniorhynchus* populations of either Seoul or other parts of Korea are not known. Tests conducted by WHOJEVRU indicate some resistance exists to certain chlorinated hydrocarbons; there also is evidence to indicate some developing resistance to organophosphorous compounds. With the wide variety of insecticides now approved for use in agriculture, it is virtually certain that insecticide resistance in vector populations will become both widespread and intensive. Such a situation now exists in parts of California where several important mosquito vectors, because of insecticides used in agriculture, now are resistant to every chemical insecticide available for their control (Ree, et al., 1971). Efforts are being made in Korea to develop alternate mosquito control methods to supplement or replace chemical control.

Existing insect control programs in Seoul would not be adequate to cope with an extensive Japanese encephalitis outbreak. These programs are conducted by nine regional health centers and are generally restricted to localities where general sanitation is poorest and insect problems most severe. Insect control operations are combined with disinfectant spraying designed to reduce insect populations and/or bacterial contamination.

b) Malaria. Since the 1950-53 period, there has been a progressive reduction in the number of indigenous cases of malaria in Korea. This has been in the absence of any organized malaria control program and is thought to be the result, in part, of the increased use of insecticides in rice cultivation with a resulting reduction in the numbers of the mosquito vector, *Anopheles sinensis*, throughout most of the country. The only remaining endemic focus is in the southern part of the country, northeast of Kyong Sang Puk-do, a mountainous region north of Pusan. Insecticide usage in agriculture there is expected to increase markedly and may reduce *Anopheles sinensis* populations, since this species, like the vector of Japanese encephalitis, breeds primarily in rice paddies and similar accumulations of fresh water. The same types of habitats in and around the Seoul area that are suitable for the breeding of *Culex tritaeniorhynchus*, i.e., unused rice paddies and fresh-water swamps, also are ideal breeding sites for *Anopheles sinensis*. As long as these exist there will be numbers of this mosquito species in the Seoul area. Malaria-infected individuals coming into Seoul from either endemic areas in Korea or outside the country could serve as infection sources for localized outbreaks of this disease, but unless conditions in Korea are drastically changed, it appears quite unlikely that any widespread malaria epidemics will occur there.

c) *Other*. Filariasis (*Brugia malayi*) is endemic in the southernmost part of Korea and on Cheju-do, but the major mosquito vector, *Aedes togoi*, is found primarily in coastal areas rather than in inland areas such as Seoul. *Anopheles sinensis* might serve as a vector of *B. malayi*, but there is no evidence thus far to indicate that it plays a major role in transmission. Through the recently organized Institute of Tropical Medicine, health officials and medical researchers are actively engaged in disseminating information concerning these diseases to medical practitioners in Korea (Koh, *et al.*, 1971) and National Institute of

Health, 1969).

3. Houseflies and Blowflies

The general sanitary conditions in the Seoul metropolitan area provide almost limitless breeding sites for both houseflies and blowflies. Both groups of flies have free access to human fecal deposits, raw foods sold in the open markets, and prepared foods sold in either unscreened restaurants or the many food-dispersing carts located throughout the city. Given the habits of these flies and the high incidence of enteric parasites and pathogens in the residents of Seoul, these insects certainly enhance the dissemination of enteric pathogenic organisms (National Institute of Health, 1969; Kim et al., 1971; Lew, 1971; Choi, Chang, and Lew, 1971).

4. Cockroaches and Lice

Koreans traditionally have associated cockroach infestations with prosperity, calling them "good fortune bugs", and have been reluctant to kill them. This attitude, however, appears to be changing. Cockroaches, like houseflies, roam freely from human fecal accumulations to food and, with the sanitary conditions that exist in Seoul, are very capable of serving as effective disseminators of enteric pathogens (Greenberg, 1971). New office buildings and apartments now have cockroach infestations that will require effective control measures. The many new apartment buildings being planned and built will require effective preventive treatments with insecticides if additional problems are to be avoided. Traditional homes do not become infested. Cockroaches are primarily pests in most occidental urban areas, but in Seoul they must be considered to be potentially important vectors of a variety of enteric diseases.

While both epidemic typhus and louse-borne relapsing fever have appeared in epidemics in the past, neither of these diseases is presently considered to be a significant public health problem in Korea (Ministry of Health and Social Affairs, 1969a). The incidence of pediculosis in the Korean population, as with these two diseases, has progressively diminished as the general standard of living has improved. Barring major man-made or natural disasters, it is rather unlikely that either of these diseases will become a significant problem in Seoul.

5. Agricultural Pests

The major crop in Korea is rice and its major pest is the stem borer (*Chilo spp.*). Rust is also an important problem and leaf hoppers can cause trouble. Due to time limits, this review may not reflect all current knowledge and thinking on these pests.

According to Dr. Hyun Jai-Sun, College of Agriculture, Seoul National University, about 70 percent of the recent increase in the yield of rice can be attributed to the use of insecticides and fungicides. Cultural practices, including the use of compost fertilizer, inorganic fertilizer, and new strains of rice have also contributed. Plans are now underway to make extensive use of IR667, which is said to increase yields by 30 percent. This estimate has not stood the challenge of the real world, and several qualified people are skeptical and rightfully concerned about the unpredictable consequences of reducing genetic diversity over wide areas. The recent U.S. corn blight has provided a meaningful lesson within academic circles, and the current rice crisis in the Philippines (birthplace of the miracle rices) is even closer to home. IR667 is now resistant to rust in Korea, but has been found highly susceptible to rust at the International Rice Research Institute in Los Baños, Phillipines.

The rice stem borer (Chilo supressalis) overwinters in the larval stage in rice straw and stubble. The relative number of borers that remain in the field stubble is unknown. Some poorly drained fields remain partially flooded, but the larvae can survive submersion for 40 days. Two generations are produced during the summer, the second of which causes the most damage. Control in many areas is compulsory and is based on heavy applications of organophosphorous (OP) compounds such as Sumithion. Although the use of Parathion has been outlawed in Korea, other OP's are hazardous to use under conditions of constant exposure by operators.

Literally hundreds of spray operators have been killed in recent years, presumably because they failed to exercise proper precautions. The success of the destructive second generation of borers is related to that of the first, and what is known of the ecology of this species in Korea suggests alternatives to the total dependence on pesticides for control. Burning most of the straw with the stubble soon after the harvest would be of obvious benefit if the straw were not useful to the farmer. However, rice straw is used extensively for thatched roofs in rural villages and the thatch must be replaced every two years. It has several other uses such as for baskets, bags, mats and hats. Other possibilities exist to destroy the borer and researchers are aware of the problems. However, judging by the review on the control of paddy stem borers by cultural practices conducted in 1964, the miracle of modern pesticides seems to have stifled research on alternative methods for many years.

An excessive reliance on insecticides coupled with the diffusion of a genetically uniform variety of high-yielding rice, such as IR667, could lead to an untenable ecological situation in the rice-growing areas of Korea. Not only will Chilo populations be under pressure to select for resistance, but genetic resistance in the IR667 to rust cannot be expected to last. Moreover, the planting of a single variety of rice over a wide area invites epidemic outbreaks of disease carried by wind or insects, such as leafhoppers.

6. Pesticide Residues and Toxicity

There is considerable concern regarding the environmental and toxicological hazards associated with the use of pesticides of all types (Rust *et al.*, 1971). In past years, there have been many chemicals and formulations available for use by the farmers. It is felt, however, that the selection of proper materials in general is beyond the competence of many of these individuals (Kwon, 1971). There now is a strong emphasis on reducing the number of chemicals approved for agricultural use and to eliminate, as soon as possible, all of the persistent organochlorine pesticides that might cause environmental pollution or toxicological problems. DDT now is approved only for use on trees and will be phased out completely as soon as suitable substitutes can be found for the presently approved uses. Other organochlorine insecticides are to be eliminated from use of food crops as soon as possible.

Many of the less persistent insecticide chemicals that have been substituted for the organochlorine compounds are much more toxic, and the use of these materials has resulted in numerous accidental poisonings. To minimize this hazard, an arbitrary $LD_{50}$ has been established for pesticide chemicals, and import permits are not now approved for any chemical or formulation which exceeds this limit. Insecticide residue tolerances now approved for food crops are those established by WHO/FAO. It is the feeling of most Korean scientists interviewed that the eating habits of the Koreans are sufficiently different from other countries that specific standards should be established for Korea. Numerous studies are now being conducted to determine suitable residue tolerances for Korea.

Studies conducted by the Institute for Environmental Pollution Research, Yonsei University, have documented the existence of chemical pollution in rice, and this problem will increase. Organic mercury levels in samples of Korean rice have exceeded the upper acceptable limits recommended by FAO. High levels also have been found in rice imported from Japan. The primary source of mercury in the Korean rice is probably from mercury-base disinfectants used to control rice blight (National Institute for Agriculture, 1970). This type chemical is not approved for use on food crops, but is sold openly as a bacteriological disinfectant. It is commonly used by rice farmers despite the fact that it is not legal to use germicidal solutions for this purpose.

An additional problem associated with more extensive use of insecticides is the possibility of accidental contamination of foods or other materials being stored or transported with these toxic chemicals. Numerous examples of this have occurred in many parts of the world and similar episodes can be expected in Korea unless suitable regulations concerning the storage and transport of toxic chemicals are enacted and enforced. With the extensive use of more toxic pesticides, there also will be an increase in other accidental poisonings to workers in formulating plants as well as to individuals using these materials. It is essential that some mechanism be established to minimize these hazards and to develop suitable methods for providing appropriate medical treatment for individuals who become intoxicated with these chemicals.

No agricultural pesticides presently are synthesized in Korea. These chemicals either are imported as technical grade materials that are then formulated for use in the country or are imported in the formulations to be used. Before import permits can be obtained, either for the technical grade or finished formulations, the importer or foreign manufacturer must request testing by the Korean government and must specify the purpose for which the chemical is to be used and marketed. These requests then are reviewed and, if approved, the government issues a permit for the importation of sample lots that are then tested by the National Institute for Agricultural Materials Inspection. The testing program includes phytotoxicity, animal toxicity, and laboratory and field tests of the materials for the purposes for which they are to be used. Field tests are conducted at two test areas, one in the southern and one in the northern part of the country, and usually are continued for a period of two years. Upon completion of the tests, the data are reviewed, and if the Institute is satisfied with the results and the need for that type of material is evident, it is recommended that the import license be issued. For products that are approved for import, there are certain requirements and specifications for the label that must be placed on each package of the material that is offered for sale. Required information includes the following: directions for use, warnings as to the hazards associated with use, the chemical name(s) and concentrations of the ingredients. Information on how to use new materials that are placed on sale is disseminated through either the Office of Rural Development (apparently the equivalent of the United States Cooperative Extension Service) or by the local or area representatives of the manufacturer or formulator. To protect consumers, the Institute for Agricultural Materials Inspection also has the legal right to enter premises where pesticides are stored and obtain samples for analysis to determine whether or not the product conforms with the information contained on the label.

7. Rodent Problems and Control

Rodent pests are important, but not serious in the sense that plagues are present in either agricultural land or in humans. Control efforts and research are in a primitive state, and the national control campaigns have little permanent impact on either the environment or on the rat populations.

The very idea of squatter settlements and slums as one aspect of the process of urbanization in Korea naturally conjures up visions of hoards of rats associated with filthy conditions. However, the rat problem in the squatter settlements is probably no worse than in many of the older residential areas of Seoul at this time. This is probably due to the relatively clean nature of Koreans living in dense situations and municipal garbage collection which prevents the accumulation of food for rats. However, open garbage dumps on steep banks were observed, which could be attractive habitats for rats.

Public health problems are considered to be of minor importance despite the usual arguments for controlling rats. Rat bites were unheard of among the few people queried, but if the incidence is no higher than that in the U.S. and is not newsworthy, a lack of awareness would be likely. There is no certain evidence for the past presence of plague in Korea. Plague occurred in Manchuria about 1900 during the pandemic. The ports of entry for returning

Vietnam-based troops were carefully monitored to prevent the possible introduction of plague. A flea (*X. cheopis*) index is maintained and is always less than 1.0. Murine typhus, scrub typhus, relapsing fever, and trichinosis are either rare or absent.

Losses of grain in the field due to rats are estimated to be relatively low (4 percent), but granary rats incur heavy losses of food in proportion to their numbers. This loss is the major justification for the recent campaigns against rats.

The four campaigns so far conducted by the Ministry of Public Health and Social Affairs have been effective in making the public "rat conscious" and in providing some elementary training in control methodologies. Safety in handling poisons has been emphasized and the zinc phosphide used in the campaign during 1970-73 is a good choice for avoiding accidents and side effects. The safety record seems to be excellent. In 1973, however, there were plans to use warfarin instead of zinc phosphide.

A potentially greater hazard is associated with the rat poison which is available at a nominal sum (50 won) from licensed pharmacists at drug stores. The compound, beta methyl fluoroacetate, is not discussed in the technical literature in Korea although 1080, sodium fluoroacetate, is. The 1080 is very fast acting, has no suitable antidote, and produces secondary poisoning in animals that feed on the dead rodents. The red coloring of the beta methyl fluoroacetate is considered to be a warning, but presumably there is no warning taste or odor. The container indicates an antidote to be used in case of accidental ingestion by humans. This poison is probably very effective in killing rats, but this hardly justifies its relatively easy availability to the public.

Toxicity research on a related compound, beta fluorethylacetate, and on 1080, has been carried out by the Philippine Rodent Research Center (Barbehenn, 1972, personal communication). For the first compound, $LD_{50}$ for R.r. mindanensis was 3.6 mg/kg with 95 percent confidence limits of 0.6 to 9.8. The second, 1080, tested at 4.2 mg/kg for a range of 3.3 to 5.4, being very similar in its toxicity to R. norvegicus. Despite the wide confidence interval due to limited testing, both compounds are clearly in the same toxicity range and a bottle of FRAKILL is definitely hazardous to man. Because of its hazard to man and to non-target species, it is judged that this poison should be diluted to a concentration that would minimize its hazard by accidental ingestion and the likelihood of secondary kills.

8. Recommendations

a) Insect pests and pesticides. Support should be provided for the World Health Organization Japanese Encephalitis Vector Research Unit - National Institute of Health program to develop data for use in monitoring and controlling Japanese encephalitis in Korea. Efforts should be made to expand the insect control programs now conducted by Seoul City Health Centers to include the treatment of existing mosquito larval breeding sites suitable for the production of _Culex titaeniorhynchus_, i.e., freshwater impoundments, swamp and unfarmed rice paddies. Measures should be established to prevent or minimize water impoundments in urban and suburban areas being developed for building or industrial sites. The program for monitoring toxic residues in food, feed, and water should be strengthened and expanded. Consideration should be given to legislation and the enforcement of standards concerning the safety aspects for transportation and storage of toxic chemicals to include pesticides. If not now established, a national program should be started to disseminate information concerning the diagnosis and treatment of pesticide chemical poisonings - perhaps along the lines of regional poison control centers.

With regard to the present health hazard associated with the use of mercury-based fungicides on rice, a special monitoring effort is recommended which should be based upon acceptable levels of mercury contamination. No standard is suggested; acceptable levels should be determined from research which takes into account the average intake of rice as well as the potential for mercury contamination of other foods in the Korean diet.

b) Rodent Control. The rat problem in the city of Seoul is sufficiently similar to that of other modern cities in that no basic research seems necessary. The problem is one of developing solutions compatible with the old and new Korean culture and economy. The following principles of rat control are not new, but are worth reiteration. Emphasize education, but be sure the methods are realistic and workable. Emphasize prevention through routine sanitation and rat proofing. Organized rat killing operations should aim at specific target areas rather than at the general population. Emphasize the use of traps on individual premises. Production of a high-quality trap might be subsidized. A good trap can last for years. Children, chickens, and pets should be protected from snap traps. Live traps are perfectly safe. Very effective yet inexpensive live traps are made in Japan. Rat proofing should be an important consideration in the design of new construction. When sanitary sewers are constructed, they should be designed in ways to minimize rat harborage and to either prevent or reduce the movement of rats through the system. Such considerations will make future sewer rat problems less likely to develop and easier to control.

## H. HUMAN HEALTH IMPACTS OF URBANIZATION*

### 1. Introduction

A review of the impacts on human health related to environmental changes accompanying rapid urbanization revealed that the principal threats to health were found to be accidental injury and tuberculosis. The accidents are due to industry and automobiles, and the tuberculosis to immigration, crowding and unsanitary conditions. An increase in the number of deaths due to heart disease is probably attributable to urban stress and is exacerbated by chronic and acute carbon monoxide poisoning. Increasing respiratory illness is at least in part related to worsening levels of air pollution.

According to a 1969 nationwide nutritional survey (Ministry of Health and Social Affairs, 1969), the diet of Seoul citizens is richer in protein than that of most Koreans, except farmers. Nevertheless, the diet is marginal at best (79.5 grams protein, 2453 calories), and undernutrition-induced susceptibility to disease remains an important consideration in Seoul.

Enteric disease is an important cause of loss of human productivity in Seoul since it is a constant drain on bioenergy. Crowding, use of night soil on crops, lack of wastewater and

*Originally authored by Dr. William A. Hall (see Preface).

sewage disposal systems, inadequate water supply, and generally unsanitary conditions combine to create a situation where 73 to 85 percent of Seoul residents harbor some form of intestinal parasite. Typhoid and dysentery are problems which have yet to be solved and are under intensive investigation. The national dish, Kimchi, is one of the principal vehicles for spread of intestinal parasites, especially during summer months.

Syphilis and probably other venereal diseases are gradually spreading through the city population, a usual phenomenon accompanying urbanization. Incomplete data indicate an increase in emotional illness, but probably not out of proportion to the population increase. Alcoholism, indigency, rape and homicide appear to be increasing more rapidly than the population.

2. Data Base Problems

The establishment of firm reporting lines required for the foundation of a reliable data base in the areas of public health and preventive medicine has not yet been accomplished in Seoul. This is not unexpected in view of the rapidity of the city's growth, and the competition for scarce resources in the public sector, which relegates data collection activities to a low priority. Neither causes of death nor incidence of disease are well known.

A recent study conducted by the Korean Institute for Family

Planning revealed that nationwide a mere 23 percent of the total deaths occurring between 1969 and 1972 had been reported in the legal ten-day notification period following death. Another 45 percent were reported in under a year, while the remaining 22 percent were unreported. In 1966, only 10 percent of deaths were reported by physicians and the cause of death was mentioned in fewer than 30 percent of all deaths. Of course, even the reliability of the above-mentioned study is problematic. However, mortality data in Seoul is probably more reliable than national data.

With increasing sophistication in the medical community and the availability of more funding, the importance of reliable public health statistics is now recognized and collection is becoming financially possible. Methodology for construction of a reliable data base is under development. Despite existing inadequacies, sufficient information is available to permit detection of trends in causality as well as morbidity and mortality, and the discussion in this section reflects this judgement. It is recognized, however, that because of the limitations of the existing public health data base, interpretations of trends may vary and future information may modify judgements made now.

3. Mortality Patterns

The leading causes of death in Seoul for the period 1966 to

1968 were surveyed by Kwon (Table 17). That survey utilized relatively untrained interviewers to visit a representative sample of homes and to check deaths occurring in the family during the preceding year. The families' interpretation of the cause of death was accepted. However error-prone this methodology may be, it is at least a beginning.

Death due to accidents, related to increased industrialization and automobile traffic, increased significantly from 1966 to 1968 (Table 1[illegible]). Tuberculosis increased slightly and gastroenteritis increased dramatically, probably reflecting increased crowding. The high death rate from tuberculosis in Seoul may be due to the fact that the majority of in-migrants are in an age group which did not receive BCG vaccine. Heart disease appears on the 1967 list for the first time.

Deaths due to tuberculosis of all kinds are exactly equal to accidents (including motor vehicle accidents) as causes of death. Plainly, a person living in Seoul runs a great risk of having his life cut short by accident.

A very interesting difference in mortality pattern between urban areas and rural areas can be seen on Table 20.

Table 17

Ten Major Causes of Death in Seoul

| 1966 | | 1967 | | 1968 | |
|---|---|---|---|---|---|
| Cause | % | Cause | % | Cause | % |
| Diseases of central nervous system | 13.4 | Accidents (including motor vehicle) | 14.7 | Accidents (including motor vehicle) | 15.0 |
| Tuberculosis* (respiratory) | 9.7 | Diseases of central nervous system | 10.4 | Diseases of central nervous system | 10.4 |
| Accidents (including motor vehicle) | 9.5 | Tuberculosis* (respiratory) | 9.9 | Tuberculosis* (respiratory) | 10.0 |
| Hypertension | 7.3 | Senility | 8.0 | Gastritis, etc. | 8.8 |
| Neoplasms | 6.3 | Gastritis, duodenitis, enteritis & colitis | 7.9 | Senility | 8.1 |
| Senility | 5.6 | Heart diseases | 7.5 | Heart diseases | 7.2 |
| Pneumonia | 4.8 | Neoplasms | 7.2 | Neoplasms | 7.1 |
| Asthma | 3.8 | Infant diseases | 5.1 | | |
| Gastro-enteritis | 3.4 | Pneumonia | 4.5 | | |
| Hepatitis | 3.3 | Kidney diseases | 3.6 | | |

Source: Kwon, 1968; Kwon et al., 1968.

*Tuberculosis of all forms = 15 percent

Table 18

Rank Order of Ten Major Causes of Death in Urban and Rural Areas in Korea (Abridged)

| Rank | Urban Areas 1966 - 1967 | Rural Areas 1956 - 1960 |
|---|---|---|
| 1 | Vascular lesions of the central nervous system | Vascular lesions of the central nervous system |
| 2 | All other accidents | Gastroenteritis (unspecified age groups) |
| 3 | Senility | Senility |
| 4 | Tuberculosis (pulmonary) | Tuberculosis (pulmonary) |
| 5 | Neoplasms | Heart disease |
| 6 | Gastroenteritis (excluding newborn) | Pneumonia |
| 7 | Motor vehicle accidents | Prematurity |
| 8 | Pneumonia | Tetanus |
| 9 | Heart disease | Accidents (cause unspecified) |
| 10 | Kidney disease | Cancer |

4. Accidental Injury and Death

While the years of reporting and terminology differ slightly, the data indicate that the principal risk to life in an industrialized, urbanized setting is death by accident. Officials of the Ministry of Health and Social Affairs are deeply concerned about this problem. One official told the writer that occupational illness, injury, and death were his greatest concern as industrialization in Seoul and throughout Korea advanced.

While the data base does not allow derivation of the incidence of motor vehicle deaths in 1966 and 1967, it is possible to ascertain that of all accidental deaths in 1968 (15 percent), motor vehicle accidents accounted for a full 4.7 percent. Ranked alone, such deaths were the seventh leading cause of death in Seoul in 1968. Traffic accident statistics for 1971 and 1972 are as follows:

| | 1971 | 1972 |
|---|---|---|
| Total accidents | 21,610 | 20,186 |
| Deaths | 725 | 748 |
| Injuries | 18,481 | 16,928 |

It seems obvious that inadequate roads and sidewalks, inadequate traffic control, and increasing density of both motor vehicles and pedestrians are the principal causes of this tremendous toll on human health in the city.

Although no data were found on deaths or injuries caused by fire, in the opinion of many hospital and public health physicians injuries and deaths due to this cause have been increasing steadily over the past several years. Most of the morbidity occurs in slum areas where lanes are generally too narrow to permit access of fire fighting equipment. Pressure in the water mains is often inadequate and there is a shortage of fire fighting apparatus. In some cases, fires are contained by tearing down housing around the fire center so as to prevent spread.

Other problems appear to be inadequate building codes and poor enforcement of existing building codes--even in major office and other buildings in the downtown section. The dreadful hotel fire of December, 1971, has given some impetus to a campaign for stricter enforcement of codes, public education on building evacuation, and updating of fire fighting equipment.

5. Crowding and Transmission of Airborne Communicable Diseases

Seoul, a city of approximately 613 square kilometers, with approximately 6 million people, is one of the more densely populated cities in the world. Increased density of population results in a higher risk of contraction of airborne communicable diseases. The transmission distance is reduced, leading to increased chance that airborne viruses, bacteria and parasite eggs will survive long enough to infect others. Also encounters with infected persons are more frequent.

a) Tuberculosis. Among the serious airborne communicable diseases, tuberculosis is, par excellence, illustrative of the importance of crowding. The overall incidence of tuberculosis is declining in the Republic of Korea (5.1% in 1965, 4.2% in 1970), paralleling the decline of this disease throughout the world. Nevertheless, the Ministry of Health and Social Affairs reports a total overall increase in tuberculosis in the nation among non-BCG vaccinated persons from 59.7 percent in 1965 to 64.8 percent in 1970. However, the incidence declined in children under 15 years of age.

Table 19

Incidence of Tuberculosis in Children
1965 and 1970

| | 0 - 4 yrs. | 5 - 9 yrs. | 10 - 14 yrs. |
|---|---|---|---|
| 1965 | 10.2% | 33.7% | 69.5% |
| 1970 | 8.5% | 26.1% | 59.1% |

The decline reflects the benefits of the program instituted in 1962, under the combined auspices of the Ministry of Health and Social Affairs and the World Health Organization, of BCG vaccination in all children under age five years. However, the tuberculosis rate increased in the principal urban areas. The 1971 _Seoul Statistical Yearbook_ shows admissions to hospitals for tuberculosis numbered 212,000 in 1966 and 234,000 in 1970. This increase is small in proportion to the population increase, and reflects the strengthening of home care programs.

b) _Other Airborne Diseases._ While no firm data are available, the consultant was assured by several public health specialists that the incidence of upper and lower viral respiratory infections and upper and lower bacterial respiratory infections is increasing in Seoul City, and that the incidence has been higher than that in rural areas for many years. No data are available on viral exanthems, bacterial meningitis, etc. Data on pertussis and diptheria are available, but were not reviewed.

c) Ondol Heating and Tuberculosis. Very probably, the *ondol* heating system contributes to the spread of tuberculosis in families since adequate heating is obtained only by reduced ventilation in the home. It has been demonstrated that tubercule bacilli are transmitted through the air and can survive suspended in warm air for more than an hour (Riley, *et al.*, 1959). It is of particular interest that tuberculosis is slightly less prevalent in the countryside where crowding is less severe and poorly constructed homes provide better ventilation.

d) Airborne Enteric Diseases. While no data are available, it should be borne in mind that crowding may contribute to the transmission of infectious hepatitis and intestinal parasites. *Ascaris* eggs and *Enterobius* eggs can be inhaled, leading to infection. No data on infectious hepatitis were found.

6. Crowding and Transmission of Waterborne and Foodborne Diseases

As is the case in airborne diseases, the reduction of transmission distance and the increased number of encounters are important aspects of crowding in water- and food-borne diseases. In a recent study, approximately one percent of apparently healthy persons in Seoul were found to be typhoid carriers, and approximately 0.7 percent were Shigella carriers (Choi and Lew, 1971). This study has been strongly criticized by other Public Health experts, however.

Table 20

Prevalence Rates of Intestinal Parasites in Korea and Seoul
(in percent)

| | 1970 Korea | 1970 Seoul | 1949 Seoul |
|---|---|---|---|
| Positive for 1 or more Helminths | 73.1 | 75.9 | 95.2 |
| Ascaris | 46.0 | 34.0 | 81.4 |
| Trichuris | 46.8 | 65.0 | 86.8 |
| Hookworm | 6.8 | 3.4 | 38.4 |
| Trichostrongylus | 7.0 | 3.9 | 35.3 |
| Clonorchis sinensis | 12.1 | 2.5 | 5.4 |
| Enterobius vermicularis | 1.6 | 2.0 | - |
| Hymenolepis nana | 0.7 | 0.5 | - |
| Entamoeba histolytica | 6.4 | 4.8 | 4.8 |
| Entamoeba coli | 20.5 | 16.3 | 26.4 |
| Giardia lamblia | 5.1 | 3.8 | 3.6 |
| Endolimax nana | 10.0 | 5.4 | 8.4 |

Source: Kim, C.H., et al., 1971

A very high prevalence of intestinal parasites were found in Korea in another recent study (Kim, C.H., et al., 1971). Prevalence rates are shown in Table 20. The reliability of this study is subject to question owing to the inexplicably low Enterobius rates shown.

Other studies have found even higher rates of incidence. Intestinal helminth infection rates of 90.5 percent in rural people and 85 percent in Seoul are reported by Byong Seol Seo, in The Korean Journal of Parasitology (Vol. 7, No. 1, 1969). Nationwide Entamoeba hystolytica infection rates of 10 percent are reported by Kim et al. (1971).

Staggering as the more recent data on infection rates may be, comparison with the 1949 rate shows a considerable improvement, most importantly in hookworm infestations. This has not been paralleled by improvement in E. histolytica infections. One may conclude that foodborne infections have declined, but the continuing high incidence of E. histolytica probably indicates water contamination with sewage, general resistance of this disease to therapy, and the tendency for infected persons to become asymptomatic carriers.

In summary, the overall population of Korea currently shows infection with one or more intestinal helminths or protozoans at rates of between 73 percent and 90 percent. Yet, it is not possible to draw conclusions concerning the impact of rapid urbanization on intestinal helminth and protozoan infections. The need for more intensive and coordinated investigations along with full scale treatment programs is obvious.

Small outbreaks of typhoid, Shigella dysentary, and cholera have been reported from Seoul and will be discussed below in connection with water pollution. No data on viral hepatitis were found.

7. Air Pollution Impacts

United States air quality criteria for nitrogen oxide indicate that adverse health effects, such as increased susceptibility to respiratory infections and impaired ventilatory function, are seen when the mean 24-hour $NO_2$ concentrations are at levels as low as 0.062 ppm. This level appears to be exceeded in Seoul according to the few measurements that have been made (see section F). A 1971 report (Korean National Academy of Sciences, 1971) presented trends of $NO_2$ levels in Seoul (Table 21).

While explicit comparisons cannot be made since the time periods averaged are not clear, it is quite evident from the data that the health of Seoul citizens in residential areas is already threatened and levels in industrial and semi-industrial areas are dangerously high. Even the parks have unhealthy air by United States standards.

Table 21

Concentrations of $NO_2$ by the Area in Seoul
24-Hour Averages (Units in ppm)

| Year | Industrial Area | Semi-Industrial Area | Commercial Area | Residential Area | Green Area (Parks) |
|---|---|---|---|---|---|
| 1965 | 0.085 | 0.045 | 0.058 | 0.029 | 0.024 |
| 1967 | 0.160 | 0.218 | 0.164 | 0.089 | 0.079 |
| 1968 | 0.260 | 0.198 | 0.129 | 0.100 | 0.082 |
| 1969 | 0.454 | 0.238 | 0.157 | - | - |

Source: Korean National Academy of Sciences, 1971

Unfortunately, there are no hard data on human health problems related to these extremely high levels of air pollution. However, many physicians contacted assured the consultant that a very large increase in patients with acute upper and lower respiratory infections, chronic bronchitis, and bronchiectasis has been seen in Seoul hospitals in recent years.

Daily ambient air averages for carbon monoxide (CO) run about 33.37 ppm, but are up to 3 times as high in the downtown area. The number of cases of acute and chronic carbon monoxide poisoning in Seoul increases annually. Ondol heating appears to be an important factor in this threat to health due to incomplete combustion of fuel resulting in high carbon monoxide generation. Kwon's (1967) study revealed hazardous conditions by Korean standards (room levels of CO above 100 ppm) in 62 percent of all living rooms and in 72 percent of all kitchens tested. Slum houses were higher in CO than "ordinary" houses, farming area houses showed the lowest of CO generally; 30 percent of living rooms and 48 percent of kitchens showed unsafe levels.

Sohn's (1967) study shows increasing morbidity from CO poisoning from 1964 through 1966. The highest CO levels were found in homes of the very poor and of the wealthy. Sohn concludes that incomplete combustion of fuel in poorly constructed furnaces accounts for the first case, while inadequate ventilation as a result of improved construction of houses accounts for the second. Exposure to 10 ppm of carbon monoxide for about 8 hours tends to dull mental performance and the United States Environmental Protection Agency considers CO levels above 10 ppm to be unsafe. One can hardly avoid the speculation that the high morbidity and mortality rates in automotive accidents in Seoul may be related to excessive home carbon monoxide levels, high ambient and very high street level concentrations of carbon monoxide. The increasing industrial accident rate may also be related. Dulling of mental performance may be compounded by visual impairment. Beard and Wertheim, in unpublished data at Stanford, have found reduction of visual acuity of up to 17 1/2 percent after only one hour's exposure to 50 ppm of CO.

Interesting also is the increase in deaths due to cerebrovascular accidents seen in Seoul hospitals. It is quite possible that some deaths due to cerebral ischemia may be precipitated by the diminished oxygen-carrying capacity of blood heavily loaded with carboxyhemoglobin. Also one can hardly avoid the conclusion that diminished blood oxygen-carrying capacity may be a strong contributing factor to morbidity and mortality due to heart disease in the city. Death due to heart disease appeared on the Seoul list of ten most common causes of death for the first time in 1967. There is abundant evidence in the United States that ischemic heart disease is exacerbated during episodes of heavy air pollution.

With respect to human productivity and general well-being, it must be concluded that air pollution, particularly carbon monoxide pollution, has reached a very serious level in Seoul. Motor vehicles and ondol home heating appear to be the principal contributing factors in carbon monoxide pollution. Ambient room air levels considered dangerous by Korean public health authorities (100 ppm) appear to be set far higher than are consistent with unimpaired mental performance and visual acuity.

The health consultant was unable to find sufficient data on other important air pollutants such as PAN, hydrocarbons, lead, nickel, cadmium, etc., from which to draw conclusions.

8. Water Pollution Impacts

Table 22 shows the incidence of typhoid and cholera in Seoul from 1965 onward. These figures indicate that Seoul City has made little progress toward controlling these important diseases, although the number of typhoid deaths has declined in recent years.

Table 22

Incidence of Typhoid and Cholera, Seoul, 1965-1972

| | Typhoid | | Cholera | |
|---|---|---|---|---|
| Year | Cases | Deaths | Cases | Deaths |
| 1965 | 840 | 28 | None reported for 1965-1968 | |
| 1966 | 803 | 18 | | |
| 1967 | 405 | 19 | | |
| 1968 | 265 | 2 | | |
| 1969 | 864 | 15 | 43 | 1 |
| 1970 | 1154 | 19 | 0 | 0 |
| 1971 | 729 | 12 | 0 | 0 |
| 1972 | 1204 | 4 | 0 | 0 |

Source: Seoul City Annual Report, 1971; and (for 1971 and 1972) Section of Public Health and Preventive Medicine, Seoul Metropolitan Government.

Piped water was supplied to 87.1 percent of Seoul residents in 1972. It is widely known among public health physicians that many shallow wells are still in use in the slum areas, and some old shallow wells remaining in central Seoul have been used during times of water shortage. Kwon (1967) in his investigation of slum area wells found that 67 percent of wells inspected were located close to and below latrines. Many wells revealed heavy coliform counts and were so shallow as to be washed out during heavy rains.

Of all water pumped from water treatment plants, approximately 40 percent is unaccounted for. Old piping, faulty connections, and cracking of piping, where it is laid above the frost line, probably account for much of the loss. While public officials deny back pressure due to inadequate water supply for several years, many private citizens speak of frequent loss of pressure at the tap. Wherever and whenever back pressure does occur a serious hazard is created, since leaking privies are often located close to water connections.

The collection and disposal of night soil in Seoul creates public health problems at every step. Night soil collection and delivery routes run along public thoroughfares and a certain amount of leakage from trucks occurs. The tracking of night soil from streets into homes is an ever present danger, especially during the warm and rainy summer. Night soil collected in trucks is, for the most part, delivered to huge collection basins where it is allowed to digest and concentrate by evaporation and ground filtration. The concentrated product is then bagged and sold. One difficulty is that parasite eggs can survive for up to nine months under cold conditions. The collection basins often overflow during the rainy season, and in some cases the overflow goes directly into tributaries of the Han River. Squatter housing is often located nearby the collection basins. The consultant observed water being pumped from a dug well, less than 50 feet from one of these basins.

All hospital liquid wastes go more or less directly into the Han River since no sewage treatment is in operation. Recent experience in the United States and elsewhere has shown that antibiotic resistant organisms are common in city sewage, and that the resistance factor can be transmitted to previously sensitive strains of bacteria. During warm and high water periods it is not difficult to predict pollution of shallow wells with E. coli, V. cholerae, Shigella, and other bacteria which have acquired resistance to one or more antibiotics. A potentially serious hazard to human health exists whenever hospital wastes go untreated.

Pollution of the Han River Estuary and other river estuaries has already resulted in deterioration of the fishing industry. Many oyster beds have been condemned and fisheries along the coast have turned up as high as 13 percent fish and 33 percent cuttlefish contaminated with enteric bacteria.

The main water pollutants from the approximately 4,000 factories located in Seoul are thought to be sulfuric acid, mercury and wastes from food processing. A few zinc mines are still in operation. Since zinc and cadmium are always found together in nature it seems likely that mine drainage may pollute the Han River with some amount of cadmium. Facilities are not available at this time for sophisticated monitoring of heavy metal and other industrial pollutants which might constitute health hazards. Fortunately, most industrial outfalls are located downstream of Seoul City water intakes.

A great deal of "close-in" farming is carried out, even within the Seoul City limits. Much runoff takes place from these farms as well as from river basin farms throughout the several drainage areas. Fertilizer runoff, either in the form of night soil or processed fertilizer, presents a continuing hazard to human health. Heavy fertilization with nitrates, with subsequent degradation to nitrites, constitutes an important child health hazard in farming areas, especially where shallow wells are used for drinking water.

Most of the Han River immediately accessible to the Seoul public is so badly contaminated now as to be unsafe for swimming and unattractive for general recreation purposes. Yet the river banks constitute, for practical purposes, the principal accessible outdoor recreation areas. Stabilization of water flow throughout the year, as is proposed for the Han near the city, is not likely to improve the river's potential recreation value unless it is accompanied by appropriate sewage treatment. In view of the multiple sewage outfalls along the riverbanks of the city, treatment sufficient to allow intensive recreational use of the Han in Seoul is a distant prospect.

Current plans call for extensive development of several river basins in order to provide flood control, low-flow augmentation, irrigation, and hydroelectric power. The distribution of the snail vectors of Liver Fluke and Lung Fluke disease may be influenced by changes in water flow and distribution. Since the Korean people are avid consumers of raw or partially cooked fish and crabs, this potential health problem should be carefully investigated and monitored.

9. Contamination of Food

Although municipal statutes bearing on sanitation in restaurants, markets, refrigeration requirements, etc., exist, these do not seem to be adequately enforced. Vendors hawking unrefrigerated meat and raw fish were observed in several markets visited. Boxes of vegetables and fish can be seen resting in curbside gutters, bathed by gutter fluids. Restaurant inspections are said to be frequent, but closures due to improper sanitation are infrequent. Refrigeration in the home is an uncommon luxury in Seoul, and housewives do their daily marketing under conditions described above. It has been well established that typhoid, cholera, bacillary dysentary, infectious hepatitis, most intestinal parasites, and several forms of viral and staphlocococcal enteritites are readily transmitted under conditions such as these. When it is recalled that many fish, oysters, and vegetables are eaten raw or only partially cooked, the prevalence of enteric infections (both acute and chronic) in Seoul can be readily understood.

It is predictable that these illnesses will increase in frequency as an increasing number of housewives are forced to shop daily in market places where sanitary conditions are, by Western standards, appalling. Where unrefrigerated meat is displayed for hours on end, unrefrigerated fish and vegetables are displayed in porous containers resting in the gutter, and where only the most desultory clean-up procedures are practiced, the public food market becomes a major focus for the transmission of enteric disease.

Trichinosis is unknown in the Republic of Korea, according to public health officials, but Cysticercosis is a problem, especially in view of its virtual incurability. In Dr. Hall's opinion, the trichina organism must exist in Seoul. The absence of clinically detectable cases is difficult to explain, however. It is possible that infected persons may not come to medical attention for some reason. In any case, the existence of the parasite mandates careful handling of garbage. Any garbage fed to swine should be cooked thoroughly.

No discussion of food sanitation in Korea would be complete without comment on Kimchi. This preparation of pickled and partially fermented vegetables is eaten by virtually all Koreans, past weaning age, at least once each day. This dish is undoubtedly responsible for much of the prevalence of intestinal parasitism in the population of Korea. Ascaris eggs remain viable for many months in this preserve. Various methods for eliminating viable eggs have been tested, but no economical and safe method has been found. The contamination of vegetables by night soil and in the market place is responsible for the importance of this food as a vehicle for the transmission of intestinal parasites. The magnitude of this problem in Seoul is increased by the large scale of the food production and processing methods necessary to nourish the dense city population.

10. Anemia and Urbanization

Despite the very high iron content (Ministry of Health and Social Affairs, 1969) of the Korean diet, low blood hemoglobin levels are found throughout Korea. No concrete data could be found for Seoul, but hospital physicians state that blood hemoglobin levels average between 10 and 12 percent (United States averages 13.5 to 15.5 percent). Beyond doubt, the low blood hemoglobin levels in Korea are the result of the heavy intestinal parasite infestation found throughout the country. In Seoul, anemia, resulting in lowered oxygen-carrying capacity of the blood, is of special importance because of the high carbon monoxide levels in the ambient air and especially high levels in homes due to <u>ondol</u> heating, since carboxyhemoglobin further lowers the oxygen-carrying capacity of the blood.

11. <u>Noise Pollution</u>

The Seoul Institute of Hygenic Laboratories has found increasing levels of noise pollution throughout the city. In 1971, the mean daily level of noise pollution in the city was between 75 and 80 decibels, while a 1969 study (Chul, <u>et al</u>., 1969) showed mean levels of 65.9 decibels, but with peaks at the city center as high as 85.2 decibels (mean daily levels). Such levels of noise pollution are not conducive to sound sleep. It is perhaps a fortunate situation that a midnight curfew has been in effect for many years. Studies in American cities reveal that noise levels in this range impair intellectual performance and decrease productivity. However sketchy the existing evidence in Seoul may be, it is impossible to avoid the conclusion that such high levels of noise diminish the quality of life wherever they occur and very likely make inroads on the psychological balance and sense of well-being.

## 12. Venereal Disease

Urbanization and prostitution go hand in hand all over the world. The 1971 Seoul Statistical Yearbook shows a definite increase of prostitution, but a diminished incidence of clinical syphilis admissions to Seoul City hospitals. However, another study (Lew and Kim, 1968) shows an increase in positive serologic tests for syphilis in otherwise normal pregnant women from 1.7 percent in 1959 to 6.9 percent in 1966. Also in 1966, a mass survey of presumed healthy soldiers showed an astoundingly high seropositive incidence of 10.9 percent.

The ready availability of penicillin in Korea is a confusing factor in attempting to analyze the pattern of syphilis in the country, but the concensus of physicians consulted was that the disease is increasing nationally. The rise of syphilis has been accompanied by a gradual spread of the disease in the population. In a 1965 survey of 1275 young men infected with syphilis, it was shown that they had contacted prostitutes in 18 percent of the cases, businesswomen 25 percent of the cases, female students 20 percent of the cases, and 32 percent with others (see The Korean Journal of Dermatology, Vol. IV, No. 1, 1965). A 1972 study of Seoul prostitutes conducted by the National Institute of Health showed positive serological tests for syphilis in only 7.9 percent of the 403 tested.

such as thefts declined rather markedly, while others such as "cruelty" increased sharply. The crimes of rape, homicide, and forgery of identification papers have also increased. Arrests for prostitution rose from zero in 1965 to 490 in 1970, while arrests for narcotic offenses have fallen from a high of 750 in 1966 to only 3 in 1970. No trends can be discerned.

No data on alcoholism are available, but Seoul physicians assured the consultant that drunkeness and chronic alcoholism are becoming increasingly serious in Seoul. Similarly, the incidence of hypertension is thought to be increasing, but no concrete data are available.

14. Recommendations

Some of the recommendations presented here related to public health considerations overlap with recommendations in other parts of this review. However, they are repeated in view of the public health significance.

a) Public Health Information. An accurate and firm reporting system for human birth, illness, injury and death should be developed. Adequate data processing equipment is essential. This should be the responsibility of the Ministry of Health and Social Affairs.

Representative sample surveys, and research if necessary, should be undertaken at suitable intervals in order to monitor the incidence of various diseases in Seoul's population. The data should be developed in order to permit the formulation of causal relationships with trends in environmental quality, as established by air and water pollution monitoring and other monitoring efforts.

Research is suggested on the relationship between nutritionally-induced anemia and carbon monoxide pollution, and the consequent effects on human health and performance.

Better communication between the City of Seoul and national agencies involved in environmental and human health concerns should be developed.

The research program and staff of the National Institute of Health should be strengthened.

b) Water Supply. Contamination by human excrement of the water supply should be more effectively prevented by the elimination of unlined outhouses and holding tanks, the elimination of shallow unlined wells, the extension of a sanitary sewer network, and the use of improved or interim methods of night soil collection and treatment which reduce water pollution and food contamination. The recommendation recognizes that the City of Seoul is already working in all of these areas. Leaks in the distribution system and other causes of low pressure should be corrected, to safeguard the potable water as well as ensure adequate pressure for fire fighting.

Water pollution monitoring should analyze for coliform count, in the Han River and its tributaries where human exposure is probable, as well as in shellfish grounds.

Urban wells in the vicinity of farming areas should be monitored for nitrites and toxic pesticides.

The future water supply reservoir should be protected from pollution by sewage, agricultural runoff and industrial wastes.

c) Health and Transportation. Carbon monoxide and nitrogen oxides should be continuously and systematically monitored in the heavily trafficked central city (within the 5 kilometer ring) and in the vicinity of schools and hospitals.

Additional means should be considered of preventing automobile traffic congestion in the central city where pedestrian traffic is densest.

Motor vehicle emission standards should be explicitly legislated and rigorously enforced.

d) Health Care. Premarital serologic tests for syphilis should be required by law. Means for venereal disease detection and control among prostitutes and entertainers should be strengthened. Serologic tests on all school children would be an important step in detection.

Tuberculosis detection and treatment capabilities should also be strengthened and improved.

Systems for equitable distribution of health care throughout the city, and the nation, should be pursued, and public health and preventive medicine facilities should be bolstered. Perhaps the most practical strategy would be the development of a corps of intermediate health care professionals.

e) Codes and Administration. Legislation bearing on industrial health and safety should be improved and rigorously enforced.

Stronger building codes, especially with respect to fire safety, should be developed and rigorously enforced. Building operation and maintenance should be subject to careful monitoring and enforcement.

Sanitary codes and licensure requirements for restaurants, markets and food processing plants should be improved, and appropriate inspection procedures should be developed. Measures to eliminate unlicensed food vendors should be taken. Milk production should be carefully monitored.

f) The Ondol. Alternatives to the *ondol* heating method should be researched. This is a matter of highest priority in the protection of health and safety of the people. As an intermediate strategy, improvement of *ondol* heating to protect dwellings against carbon monoxide accumulations may be possible.

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## Appendix A

List of Persons in Seoul Interviewed by U.S. Scientists

Mr. Carl F. Bartz, Jr.
First Secretary (Cultural)
American Embassy
Korea

Ms. Ann Casey
Principal
Nursery school (serving both wealthy Korean children and scholarship students from a squatter area near the school)

Dr. Cha Chul-Hwan
Associate Professor of Preventive Medicine
Director
Health Center
Seoul National University

Mr. Chick Hong-Sung
Department of Sociology and Asiatic Research Center
Korea University

Dr. Chin Thack-Loh
Professor of Parasitology
Yonsei College of Medicine
Director
Institute of Tropical Medicine

Mr. Cho Do-Yeon
Chief
Biological Assessment Division
National Institute for Agricultural Materials Inspection

Mr. Choe Sang-Chul
Department of Urban and Regional Planning
GSPA
Seoul National University

Mr. Chon Soon-Pyo
Plant Protection Division
Ministry of Agriculture and Forestry

Mr. Keith D. Christian
Environmental Planning Group
Korean Institute of Science and Technology

Mr. Chu Hyun-Bai
Agricultural Economics Research Institute

Dr. Hahn Sang-Joon
President
Korean Institute of Science and Technology

Mr. Newman Hall
Chief
Office of Science and Technology
USAID
Korea

Mr. Han Bae-Ho
Department of Political Science and Asiatic Research Center
Korea University

Mr. Richard H. Harris
Sanitary Engineer
World Health Organization

Mr. Hu Yong
Director
National Institute of Health

Dr. Huh Young
Professor of Health Administration
Seoul National University

Dr. Hyun Jai-Sun
Department of Agricultural Biology
Seoul National University

Mr. Pierre H. A. Jolivet
Project Leader
World Health Organization Japanese Encephalitis Vector Research Unit

Mr. Kim An-Jae
Graduate School of Public Administration
Seoul National University

Mr. Kim Chin-Myun
Weather Service Department
Central Meteorological Office

Dr. Kim Chung-Kun
Professor of Biostatistics and Ecology
Seoul National University

Dr. Kim Hon-Kyu
Entomologist
Ewha Women's University

Mr. Kim Hyo-Sang
Chief
Public Nuisance Measurement Section
Institute of Hygiene
Seoul City

Dr. Kim Il-Soon
Professor
Department of Preventive Medicine
Yonsei College of Medicine

Dr. Kim Jong-Kun
Professor of Epidemiology
Seoul National University

Mr. Kim Jong-Suk
Deputy Chief Examiner
Public Nuisance Measurement Section
Department of Hygiene
City of Seoul

Mr. Kim Jun-Yop
Director
Asiatic Research Center
Korea University

Dr. Kim Ki-Ho
President
Korean Academy of Tuberculosis
Yonsei College of Medicine

Mr. Kim Kyoung-Ho
Director
Department of Virology
National Institute of Health

Mr. Kim Myung-Ho
Professor
Department of Preventive Medicine and Public Health
College of Medicine
Yonsei University

Mr. Kim Woon-Tai
Dean
Graduate School of Public Administration
Seoul National University

Dr. Kim Yu-Sun
Chemistry Division
Atomic Energy Research Institute

Dr. Kwon Sook-Pyo
Professor
Department of Preventive Medicine
Director
Institute for Environmental Pollution Research
Yonsei University

Mr. Kwon Tai-Joon
Department of Urban and Regional Planning
GSPA
Seoul National University

Mr. Lee Hae-Young
Department of Sociology
Director
Population and Development Studies Center
Seoul National University

Mr. Lee Hong-Koo
Department of Political Science and Population Development Studies Center
Seoul National University

Mr. Lee Hyo-Jae
Department of Sociology
Ehwa University

Mr. Lee In-Shik
Director
Sungdong Ky Health Center
Seoul

Mr. Lee Man-Gap
Department of Sociology
Seoul National University

Dr. Lee Song-Hi
Director
Public Health Bureau
Ministry of Health and Social Affairs

Dr. Lee Sung-Woo
Chief
Public Health Section
Ministry of Health and Social Affairs

Mr. Lee Young-Sik
Chief
Housing Control Division
Seoul City Government

Dr. Lew-Joon
Professor of Microbiology
Yonsei College of Medicine

Mr. Lim Hee-Sop
Department of Sociology and Asiatic Research Center
Korea University

Mr. Lim Song-Ki
Chief
Environmental Section
City of Seoul

Mr. Gregory Pai
Institute of Urban Studies and Development
Yonsei University

Dr. Pak Chae-Ju
Director
Institute of Hygiene
City of Seoul

Mr. Pak Kyong-Yoon
Health Physics Division
Atomic Energy Research Institute

Mr. Park Chae-Joo
Director
Seoul Metropolitan Institute of Hygiene

Mr. H. I. Ree
Chief
1st Entomology Division
Department of Virology
National Health Institute

Mr. Donald Reilly
AID
United States Mission

Dr. Rhee Chon-Juh
Head
Environmental Studies Group
Korean Institute of Science
and Technology

Mr. Rhee Choong Sheek
Chief
National Nutrition Office
Ministry of Health and Social
Affairs

Mr. Rhee Ju-In
Vehicle Control Section
City of Seoul

Dr. Rho Chae-Shik
Director
Health Physics Division
Atomic Energy Research
Institute

Mr. Rho Chung-Bai
Chief
Department of Hygiene
National Institute of Health

Mr. Ro Chung-Hyun
Director
Institute of Urban Studies
and Development
Yonsei University

Dr. Ron In-Kyo
Professor of Epidemiology
Seoul National University

Mr. Shim Sang-Chil
Director
Radiation Agriculture Research
Institute (RRIA)
Office of Atomic Energy
Republic of Korea

Mr. Shin Han-Kwon
Chief
Plant Protection Division
RRIA

Mr. Shin Jong-Dae
Chief
Bacteriological and Seriological
Section
Seoul Metropolitan Institute of
Hygiene

Mr. Shin Kyong-Shick
Chief
Waterworks and Sewage Division
Ministry of Construction

Mr. Shin Young-Kul
Management Section
Agricultural Administration
Ministry of Agriculture and
Forestry

Mr. Soh Chin-Thuck
Professor of Parasitology
Director
Institute of Tropical Medicine
Yonsei University

Mr. Sohn Yung-Mok
Coordinator of Planning
City of Seoul

Mr. Donald Thomas
AID
United States Mission

Dr. Whang Kyo-Bok
Leader
Transportation Economics Group
Korean Institute of Science
and Technology

Dr. Won Pyong-Hwi
Dong Kuk University

Dr. Won Pyong-Oh
Ornithologist
Kyung Hee University

Dr. Yang In-Ki
Director General
Central Meteorological Office

Dr. Yang Jae-Mo
Professor
Yonsei College of Medicine

Mr. Yoon Jong-Joo
Department of Sociology
Seoul Women's College

Mr. Youn Hong-Taek
Institute of Urban Studies and
Development
Yonsei University

## Appendix B

List of Korean and United States participants in the August 8-9, 1973, workshop on the Smithsonian Institution case study of Seoul's environment.

Mr. Ahn Byong-Tai
Chief
Agricultural Section
Special City of Seoul

Dr. Cha Chul-Whan
Professor
College of Medicine
Korea University

Dr. Choong Mun-Sik
Professor
Graduate School of Public Health
Seoul National University

Mr. Chung Kyu-Young
Director
Bureau of Water Supply
Special City of Seoul

Mr. Chung Sae-Young
Chief
Sewage Section
Special City of Seoul

Dr. Kim Duk-Hyon
Director
MOST

Mr. Kim Hyo-Sang
Chief
Food Analysis
(Former Chief of Air Pollution Measurement)
Institute of Hygienic Laboratories
Special City of Seoul

Mr. Kim Hyong-Bun
Chief
Water Supply Section
Special City of Seoul

Mr. Kim Jong-Suk
Chief
Air Pollution Measurement
Institute of Hygienic Laboratories
Special City of Seoul

Dr. Kim Jung-Kun
Professor
Graduate School of Public Health
Seoul National University

Mr. Kim Suk-Soo
Chief
Water Pollution Measurement
Institute of Hygienic Laboratories
Special City of Seoul

Mr. Kwak Hwo-Sup
Director
Bureau of Housing
Special City of Seoul

Dr. Kwon Suk-Pyo
Professor of Environmental Health
College of Medicine
Yonsei University

Mr. Lee Choong-Woo
Chief
Office of Municipal Administration
Special City of Seoul

Mr. Lee Han-Il
Chief
Insect Section
National Institute of Public Health

Miss Lee Hyo-Jae
Professor
Department of Sociology
Ehwa Women's University

Dr. Lee Sung-Woo
Chief
Public Health Section
Ministry of Health and Social Affairs

Mr. Lee Woo-Young
Director
Bureau of Environment
Special City of Seoul

Dr. Lim Han-Jong
Professor
College of Medicine
Korea University

Mr. Lim Song-Ki
Chief
Environmental Section
Health and Social Welfare Bureau
Special City of Seoul

Mr. Liu Ik-Hyon
Chief
Section of Disease Prevention
Special City of Seoul

Dr. Oh Kae-Chil
Professor
Department of Environment
Suhkang University

Dr. Pak Jung-Hyon
Professor
College of Engineering
Seoul National University

Mr. Rhee Chan-Juh
Leader
Environmental Studies Group
KIST

Dr. Ro Chae-Shik
Director
Health Physics Division
Atomic Energy Research Institute

Dr. Ro Chung-Hyun
Director
Institute of Urban Studies and Development
Yonsei University

Mr. Shin Jae-Young
Chief
The 2nd Cleaning Section
Special City of Seoul

Mr. Sohn Jong-Mok
Director
Bureau of Planning
Seoul City Hall

Mr. Whang Kyu-Bok
Leader
Transportation Economic Group
KIST

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## U.S. Participants

### Smithsonian Institution

Dr. Charles A Frankenhoff, Jr.
Professor
Graduate Department of Economics
University of Puerto Rico

Dr. William A. Hall
Center for Environmental Studies
Princeton University
Princeton, New Jersey

Dr. Richard J. Coughlin
Department of Sociology
University of Virginia
Charlottesville, Virginia

Mr. Peter H. Freeman
Project Manager
International Environmental Assessment Studies
Office of International and Environmental Programs
Smithsonian Institution
Washington, D.C.

Mr. William L. Eilers
Director
Office of International and Environmental Programs
Smithsonian Institution
Washington, D.C.

### AID/Seoul

Dr. Newman A. Hall
Science Advisor

Mr. James K. Thomas
Engineering Officer

## Appendix C

Water Quality Data, Han River, Seoul, 1965-1971

Table C-1. Water Quality Characteristics of the Main Han River, Seoul, at the Three Major Intakes, January-December, 1965.

| Item | (1) Goo U Ri Min. | Max. | Ave. | (2) Dook Do Min. | Max. | Ave. | (4) Norang Jin Min. | Max. | Ave. |
|---|---|---|---|---|---|---|---|---|---|
| Temperature (C) | 0 | 26.8 | 13 | 0 | 27 | 13 | 0 | 27.5 | 13.4 |
| Turbidity | 2 | 2,000 | 22 | 2 | 1,800 | 55 | 5 | 500 | 30.3 |
| PH | 5.8 | 7.4 | 7.2 | 7.1 | 7.3 | 7.2 | 6.9 | 7.6 | 7.4 |
| Total Alkalinity | 27 | 41 | 35.5 | 24 | 50 | 38 | 29 | 58 | 45.3 |
| COD (mg/1) | 0.3 | 1.3 | 0.98 | 0.48 | 1.92 | 0.79 | 0.65 | 3.3 | 1.7 |
| Total Acidity | 2 | 12 | 3.14 | 1.5 | 5.0 | 3.7 | 3.5 | 12 | 5.1 |
| Chloride Ion(mg/1) | 4.1 | 7.78 | 5.6 | 3.2 | 8.6 | 5.6 | 5.3 | 11.0 | 8.34 |
| Coliform, Count/100cc | 28 | 12,000 | 900 | 93 | 11,000 | 4,036 | 11,000 | 160,000 | 89,000 |

Source: Bureau of Water Supply, Special City of Seoul.

Table C-2. Water Quality Characteristics of the Main Han River, Seoul, at the Three Major Intakes, January-December, 1966.

| Item | (1) Goo U Ri | | | (2) Dook Do | | | (4) Noryang Jin | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Ave. | Min. | Max. | Ave. | Min. | Max. | Ave. |
| Temperature (C) | 1.3 | 27 | 12.2 | 1.3 | 27 | 12.2 | 0 | 28 | 13 |
| Turbidity | 2 | 1,600 | 33 | 2 | 2,000 | 2.9 | 5 | 1,400 | 64 |
| PH | 7.3 | 7.4 | 7.2 | 6.8 | 7.4 | 7.2 | 6.7 | 7.6 | 7.4 |
| Total Alkalinity | 22 | 38 | 34 | 14 | 42 | 32 | 24 | 50 | 38.7 |
| Total Acidity | 1 | 6 | 3.3 | 2 | 5.5 | 3.2 | 2 | 9 | 4.6 |
| COD (mg/l) | 0.48 | 2.0 | 1.04 | 0.4 | 1.84 | 0.84 | 0.41 | 2.9 | 1.14 |
| Chloride Ion (mg/l) | 4.95 | 10.62 | 6.5 | 3.5 | 12.5 | 5.8 | 5.3 | 11.7 | 7.5 |
| Coliform, count/100cc | 75 | 55,000 | 3,180 | 230 | 23,000 | 718 | 3,300 | 160,000 | 49,256 |

Source: Bureau of Water Supply Special City of Seoul.

Table C-3. Water Quality Characteristics of the Main Han River, Seoul, at the Three Major Intakes, January-December, 1967.

| Item | (1) Goo U Ri Min. | (1) Goo U Ri Max. | (1) Goo U Ri Ave. | (2) Dook Do Min. | (2) Dook Do Max. | (2) Dook Do Ave. | (4) Noryang Jin Min. | (4) Noryang Jin Max. | (4) Noryang Jin Ave. |
|---|---|---|---|---|---|---|---|---|---|
| Temperature (C) | 0 | 28.4 | 13 | 0 | 28.4 | 13 | 0 | 29 | 14 |
| Turbidity | 2 | 900 | 20 | 2 | 1,000 | 24 | 5 | 900 | 59 |
| PH | 6.0 | 7.5 | 7.3 | 6.9 | 7.3 | 7.2 | 6.9 | 7.5 | 7.4 |
| Total Alkalinity | 23 | 51 | 35 | 24 | 44 | 34 | 32 | 67 | 40 |
| Total Acidity | 1.0 | 5 | 2.57 | 1.0 | 4.5 | 2.4 | 3 | 8 | 5.3 |
| COD (mg/l) | 0.41 | 1.68 | 0.94 | 0.37 | 0.96 | 0.56 | 0.61 | 10.6 | 2.8 |
| Chloride Ion (mg/l) | 1.8 | 3.84 | 2.94 | 6.3 | 10.8 | 8.2 | 5.5 | 12 | 8.4 |
| Coliform, count/100cc | 21 | 1,100 | 259.5 | 80 | 4,600 | 1,155 | | | |

Source: Bureau of Water Supply, Special City of Seoul.

Table C-4. Water Quality Characteristics of the Main Han River, Seoul, at the Three Major Intakes, January-December 1968.

| | (1) Goo U Ri | | | (2) Dook Do | | | (3) Noryang Jin | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | Min. | Max. | Ave. | Min. | Max. | Ave. | Min. | Max. | Ave. |
| Temperature (C) | 0.5 | 26.5 | 13.3 | 0.5 | 26.5 | 13.3 | 0 | 28 | 14 |
| Turbidity | 2 | 1,000 | 25.8 | 2 | 450 | 21 | 6 | 700 | 36.6 |
| PH | 6.5 | 7.4 | 7.2 | 6.9 | 7.3 | 7.2 | 6.9 | 7.5 | 7.4 |
| Total Alkalinity | 19 | 47 | 35 | 19 | 45 | 36 | 18 | 62 | 34.1 |
| Total Acidity | 2 | 4 | 3 | 1 | 5 | 2.9 | 2.5 | 13.5 | 4.93 |
| COD (mg/l) | 0.32 | 2.0 | 1.3 | 0.36 | 2.2 | 1.4 | 0.33 | 2.4 | 1.5 |
| Chloride Ion (mg/l) | 5.6 | 9.1 | 7.07 | 7.7 | 10.7 | 8.5 | 5.2 | 14.8 | 8.85 |
| Coliform count/100cc | 21 | 1,100 | 215 | 320 | 24,000 | 2,914 | 9,500 | 160,000 | 75,60( |

Source: Bureau of Water Supply, Special City of Seoul.

Table C-5. Water Quality Characteristics of the Main Han River, Seoul, at the Four Major Intakes, January-December, 1969.

| Item | (1) Goo U Ri | | | (2) Dook Do | | | (3) Bo Kwang Dong | | | (4) Noryang Jin | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Ave. | Min. | Max. | Ave. | Min. | Max. | Ave. | Min. | Max. | Ave. |
| Temperature (C) | 0 | 25 | 11.6 | 0 | 25 | 11.6 | 1 | 25 | 12 | 0 | 27 | 12.4 |
| Turbidity | 2 | 1,000 | 31.6 | 3 | 900 | 34 | 10 | 350 | 91 | 10 | 1,100 | 50 |
| PH | 6.1 | 7.4 | 7.2 | 6.8 | 7.3 | 7.1 | 6.9 | 7.4 | 7.2 | 7.0 | 7.5 | 7.3 |
| Total Alkalinity | 23 | 48 | 33.6 | 26 | 50 | 34 | 25 | 50 | 38.8 | 30 | 56 | 45.6 |
| Total Acidity | 0.5 | 4 | 2.53 | 1.0 | 6.1 | 2.9 | 2 | 8 | 5.3 | 2.5 | 10 | 5.4 |
| COD(mg/l) | 0.32 | 5.0 | 1.3 | 0.56 | 2.0 | 1.36 | 1.3 | 3.45 | 2.48 | 0.86 | 3.9 | 1.7 |
| DO(mg/l) | 6.2 | 13.9 | 11.1 | | | | | | | | | |
| BOD(mg/l) | 0.8 | 2.16 | 1.5 | | | | | | | | | |
| Chloride Ion(mg/l) | 1.9 | 15.36 | 6.39 | 6.3 | 14.4 | 8.3 | 10.6 | 22.7 | 16.6 | 6.7 | 20.2 | 9.88 |
| Coliform count/100cc | 21 | 460 | 227 | 150 | 23,000 | 3,256 | 93,000 | 860,000 | 247,800 | 22,000 | 160,000 | 83,990 |

Source: Bureau of Water Supply, Special City of Seoul.

Table C-6. Water Quality Characteristics of the Main Han River, Seoul, at the Four Major Intakes, January-December, 1970.

| | (1) Goo U Ri | | | (2) Dook Do | | | (3) Bo Kwang Dong | | | (4) Noryang Jin | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Item** | Min. | Max. | Ave. | Min. | Max. | Ave. | Min. | Max. | Ave. | Min. | Max. | Ave. |
| Temperature (C) | 0 | 26 | 13.1 | 1 | 26 | 13 | 1 | 24 | 13.9 | 0 | 28 | 13.1 |
| Turbidity | 2 | 550 | 16.2 | 3 | 900 | 2,190 | 16 | 350 | 73 | 10 | 1,000 | 68 |
| PH | 7.1 | 7.3 | 7.2 | 6.7 | 7.5 | 7.2 | 6.8 | 7.4 | 7.1 | 6.9 | 7.5 | 7.1 |
| Total Alkalinity | 19 | 54 | 42 | 25 | 46 | 38 | 20 | 54 | 39.4 | 25 | 62 | 44 |
| Total Acidity | 1 | 4 | 2.2 | 2.2 | 4.2 | 2.9 | 2 | 12 | 5.68 | 3 | 10 | 5.8 |
| COD(mg/l) | 0.3 | 2.7 | 0.96 | 0.81 | 1.2 | 1.0 | 1.2 | 6.4 | 4.5 | 1.6 | 4.6 | 2.7 |
| DO(mg/l) | 6.7 | 14.6 | 9.8 | | | | | | | | | |
| BOD(mg/l) | 1.06 | 1.52 | 1.29 | | | | | | | | | |
| Chloride Ion (mg/l) | 7.6 | 14.6 | 9.8 | 6.8 | 8.9 | 8.1 | 10.5 | 24.8 | 15.2 | 5.3 | 21.3 | 10.8 |
| Coliform count/100cc | 150 | 1,500 | 645 | 230 | 460,000 | 6,627 | 75,000 | 1,100,000 | 320,400 | 5,600 | 240,000 | 55,935 |

Source: Bureau of Water Supply, Special City of Seoul.

Table C-7. Water Quality Characteristics of the Main Han River, Seoul, at the Five Major Intakes, January-December, 1971.

| Item | (1) Goo U Ri | | | (2) Dook Do | | | (3) Bo Kwang Dong | | | (4) Noryang Jin | | | (5) Yongdeung Po | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Ave. | Min. | Max. | Ave. | Min. | Max. | Ave. | Min. | Max. | Ave. | Min. | Max. | Ave |
| Temperature (C) | 1 | 26 | 12.6 | 1 | 27 | 12.3 | 1 | 26 | 13 | 1 | 27 | 13 | 1 | 26 | 13 |
| Turbidity | 3 | 550 | 30.2 | 3 | 700 | 32 | 28 | 800 | 250 | 10 | 750 | 77 | 28 | 800 | 250 |
| PH | 6.9 | 7.8 | 7.1 | 7.2 | 7.4 | 7.3 | 6.7 | 7.2 | 7.0 | 6.9 | 7.1 | 7.0 | 6.7 | 7.2 | 7 |
| Total Alkalinity | 20 | 44 | 32 | 26 | 49 | 45 | 27 | 60 | 43 | 34 | 57 | 44 | 27 | 60 | 43 |
| Total Acidity | 0.5 | 3.5 | 2.05 | 1 | 3.2 | 3 | 2.8 | 9.8 | 6.3 | 2.5 | 9 | 4.26 | 2.8 | 9.8 | 6 |
| COD(mg/l) | 0.3 | 1.9 | 0.79 | 0.53 | 1.64 | 1.06 | 2.0 | 6.7 | 4.2 | 0.88 | 4.4 | 2.1 | 2.0 | 6.4 | 4 |
| DO(mg/l) | 6.6 | 13.8 | 10.0 | | | | | | | | | | | | |
| BOD (mg/l) | 0.5 | 3.4 | 2.0 | | | | | | | | | | | | |
| Chloride Ion (mg/l) | 3.5 | 9.8 | 7.2 | 6.3 | 13 | 8.2 | 7.4 | 27.6 | 15.0 | 6.7 | 19.5 | 11.6 | 7.4 | 27.7 | 15 |
| Coliform count/100cc | 430 | 4,600 | 1,680 | 93 | 180,000 | 4,600 | 43,000 | 460,000 | 251,000 | 17,000 | 160,000 | 127,000 | 43,000 | 460,000 | 251,000 |

Source: Bureau of Water Supply, Special City of Seoul.