PN-ABJ-542
Original

THE EFFECT OF RAPID URBANIZATION ON WATER SUPPLY AND WATER POLLUTION

A CASE STUDY OF SEOUL, KOREA

73540

by
Perry L. McCarty

This report is concerned with special problems in water supply and water pollution control resulting from rapid urbanization in developing countrires. Seoul, Korea was used as a special case for study because of the explosive growth in population which has resulted in this city since the end of the Korean War in 1953. Experience from another country, India, was also drawn upon based upon observations made by the author while a participant in the workshop on "Water in Man's Life in India," jointly sponsored by the Indian National Science Academy and the U.S. National Academy of Science in September 1971. In order to assess the water situation in Seoul, a trip was made for the two-week period from March 13 to March 24, 1972.

The past and projected developments of water supply for Seoul, and the particular problems of water quality were studied. In addition, methods for waste disposal were investigated with special emphasis being placed on the polluting effects of the disposal methods, especially as they affect the health of the citizens and quality of receiving waters. Most of the information obtained was concerned with the disposal of household wastes and wastes from commercial activities. A portion of the sanitary waste is collected as night soil and transported to disposal sites in trucks, as is common in many Asiatic countries. Liquid wastes, however, are discharged to storm drains and sewers and eventually reach the Han River which passes through the city. Information on industrial wastes was sought, but little data was available. There are few large industries located within the City of Seoul. A major industrial complex, however, lies along the roadway between Seoul and Inchon. Discharges from these industries appear to cause severe pollutional conditions in the river, but at a point downstream from Seoul itself. Insufficient data to assess the affect of the pollution was available.

Over twenty individuals were visited during our stay in Seoul. Several officials for the City of Seoul, including those in the Bureau of Health and Social Affairs, Water Works Bureau, Sewer Section, Institute of Hygienic Laboratory, and the Cleaning Bureau were contacted. These individuals are responsible for water supply and wastewater disposal for the city. In addition, professors in the School of Public Health and Civil Engineering Department, Seoul National University, and the Department of Urban Engineering, Hang Yang University, as well as several individuals at the Korean Institute of Science and Technology who are directly concerned with environmental problems were most helpful in supplying background information. Officials in the Federal Government concerned with future developments and water projects affecting Seoul were also visited.

Field trips along the Han River were undertaken to obtain a visible feel for the quality of the river and to determine significant points of waste discharge into it. A visit was made to a water treatment plant to determine the level of technology being used. In addition, a trip was made to view the methods of night soil collection and disposal. On the weekend, a trip was made up the Han River to the small village of Duk Chon in Kangwon-do, located about 120 kilometers northeast of Seoul. This trip was valuable to obtain an impression of the rural life in Korea and to view rural water supply and waste disposal methods. This furnished a good impression of the change in environmental conditions for individuals as they move from the rural areas to the city.

Information and data was at times difficult to obtain, partly because much of the information was published in Korean. Also, when the study began in was not clear as to where particular information was located, nor what information should be sought. No doubt much helpful information which may have been available, was not found. However, it is believed that sufficient information was obtained from the various sources to form an adequate impression of the effect of rapid urbanization on water supplies and waste disposal.

HISTORICAL DEVELOPMENT OF WATER PROBLEMS DURING URBANIZATION

It is worthwhile to review the development of water supply and waste disposal problems which have occurred historically as cities have come into being and have grown in size. Such a review suggests that the nature of the problems and the way they have evolved and been approached for solution have changed little since large cities first developed. The problems have perhaps become more severe as cities have grown larger, but it is perhaps also true that the ability to grow larger has been made possible through the slow evolutionary development of adequate methods to handle waste disposal problems.

Problems of water supply and wastewater disposal are closely linked. When water is supplied to the individuals of a city then methods for carrying away the used or wastewater must be available. The Minoan Civilization 4,000 years ago had clean water brought to the Capitol, Konossos, in pressure pipes. The wastewaters were carried away in storm drains sealed with cement, while dry refuse was deposited in large pits outside the city and in earthen silos where the wastes were fermented and composted for manuring the fields. Water and wastewater systems in many countries are little different today.

The Romans adapted the Minoan system. Adequate quantities of water were available in Rome, but no means for removing filth from the city were available and it was simply deposited on the ground eventually polluting the groundwaters beyond tolerance. The simple solution appeared to be to seek water supplies from farther away, beyond the populated community, and hence the development of the aqueducts. By A.D. 100 nine great aqueducts brought water to Rome. The first aqueduct, the Appia, was built in 313 B.C.

Not that the Romans did not have drains, but they were built mainly for carrying away storm water. The main Roman drain, the Cloca Maxima, was perhaps the first large scale sewer for this purpose. Then, channels and conduits were not used to any extent for directly carrying the wastes from the individual dwellings, as requirements for public health were little recognized. Connections could be made by the property owners, however, at their own costs.

The early sewers were frequently little more than the covered channels of brooks. In England the oldest, the Ludgate Hill Sewer, was an open channel for many years. The sewer was fed by several springs and was originally a source from which people were supplied with water. It was not covered until 1732. What eventually became Ranelagh Sewer was a brook rising from a spring and as late as 1730 it furnished water for the Serpentine, the famous pond in Hyde Park.

A significant development was made in Hamburg after a fire destroyed an old part of the city in 1842. Advantage was taken of the opportunity to plan an integrated sewer system to drain the city. This was done successfully and served as a model for later developments in other cities.

A new sewer system was begun in Paris in 1833 and was originally designed to carry away storm waters, street refuse, and wastewaters (exluding human wastes) from the homes. Human wastes by ordinance in 1820 were discharged to cesspools. Into these the effete matter from water closets, greases and washings from sinks, and other such refuse was discharged. The cesspools finally became so offensive that a new system of sewerage was developed. The Europeans were divided into two schools, one favoring the "dry" and the other the "water carriage" methods of collecting material from the cesspools. In the dry method the concentrated waste was dried on soil beds or disinfected by calcium chloride or other chemicals. In other cases the excreta was collected in pails which were removed in wagons. The contents were frequently used for fertilizing purposes.

At that time there was great popular opposition to discharging fecal material into the sewers, although the sewers were available for water carriage and their contents were already fowl with the refuse washed from the streets. This opposition disappeared in time. First, a tank was placed in a drain line between the sanitary facilities in the dwelling and the sewer. This tank had as its purpose the retention of all solids discharged to the drain. Soon, popular prejudice against the water carriage system abated, the tank and its connections were removed, and the drain lines became connected directly to the sewer.

John Phillips gave testimony in 1847 as to the conditions of waste disposal in London:

> "There are hundreds, I may say thousands, of houses in this metropolis which have no drainage whatever, and the greater part of them have stinking, overflowing cesspools. There are also hundreds of streets, courts and alleys that have no sewers; and how the drainage and filth is cleaned away and how the miserable inhabitants live in such places is hard to tell.
>
> In pursuance of my duties, from time to time, I visited very many places where filth was lying scattered about the rooms, vaults, cellars, areas in yards, so thick and so deep that it was hardly possible to move for it. I have also seen in such places human beings living and sleeping in sunken rooms with filth from overflowing cesspools, exuding through and running down the walls and over the floors . . . the effects of the effluvia, stench and poisonous gases constantly evolving from these fowl accumulations were apparent in the haggard, wan and swarthy countenances and enfeebled limbs of the poor creatures whom I found residing over and amongst these dens of pollution and wretchedness."

Changes in thinking about waste disposal to sewers came about in London from a succession of epidemics of chlorea. Chlorea was discovered in London in 1848 and broke out in successive years until 1854 when it claimed 10,675 lives. The connection between contaminated water supply and the rapid spread of disease was clearly shown, and also filthy living conditions in most houses, due to the absence of effective sewerage, was a great hindrance in combatting the disease. Prior to 1850 it was against the law to discharge sewage or other offensive matter to the sewers. In order to clean up the city it was at first permitted, and then ordered that all wastes be discharged to the sewers. The cleaning up of the town was begun. Systems of intercepting sewers to collect the drainage and discharge it downstream from the city were conceived and from these decisions the concept of sewage disposal as known today in many countries of the world was begun. However, the net early result was the removal of filth from the cities to the rivers, and a new major problem resulted.

Developments in the United States were similar. In the early 19th Century sewers were used mainly for drainage of storm water and cesspools were generally employed for fecal matter. Up until 1850 Philadelphia prohibited the discharge of home waste into its sewer lines. It was not until 1833 that Boston legally permitted discharge of excreta into its public sewers. Finally, sewers became accepted as the vehicle for human waste disposal. The last city to banish cesspools in favor of the water carriage system was Baltimore which had 80,000 cesspools in 1879. It was apparent that before that time many cesspools had overflow discharging into the storm water which was contrary to law, but quite common practice.

Thus, the historical development suggests that in the absence of a water carriage system, waste disposal has been a difficult, if not impossible task. Keeping wastes from reaching storm sewers, when built, was an equally impossible task. The desire of people to rid themselves of their wastes, and the convenience of a sewer to carry wastes away has been too tempting to resist for a large number of individuals in most cities, even when prohibited by law.

However, in 1962 Fair questioned the wisdom of the original decision to discharge offensive wastes from households into the existing storm drains. This decision he felt resulted in the pollution of first the small streams and then the larger ones near the great cities of the world. His questioning was perhaps as much upon the decision to discharge the collected wastewaters to the rivers as upon the discharge of household waste to sewers. He suggested that discharge of the wastewaters on farmlands might have caused less harmful effects.

At the workshop on "Water in Man's Life in India" questions about the desirability of the water carriage system were also raised. It was asked whether the water carriage system of collection and disposal of human excreta was the ideal method for a developing country like India? What new technologies could be foreseen for the possible hygienic collection of dry wastes or "night soil?" How can the wastes from cities be treated in an economical manner? At the conference, there was general agreement that better methods for night soil collection should be sought. 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. During the author's visit to Seoul focus was directed towards possible answers to these questions.

WATER SUPPLY FOR SEOUL

The City of Seoul increased in population from less than a million in 1951 to almost six million people in 1971, twenty years later. Projections are for an increase to about seven and one-half million people in the next ten years. Growth in population has indeed been rapid. The major source of water for this city is the Han River, one of the largest in Korea with a drainage basin of 33,000 square kilometers, or slightly more than one-fourth of all the area of The Republic of Korea. The flow is very seasonal as seventy percent of the precipitation in the basin falls during the months of June, July, August, and September. The surface water resources of the Han River basin have been partially developed with five completed dams and associated hydropower plants, and numerous small reservoirs, diversion weirs, and pumping plants for irrigation. There are about 126,000 hectares of land under irrigation in the basin, mostly for rice.

Seoul City obtains most of its municipal water from the Han River, and relies on groundwater for the remainder. 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. Seoul lies near the outlet of the Han River into the Yellow Sea and 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. There are presently five 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 parallel 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 1. Although water rationing has been necessary in recent years, the capacity is now believed such that rationing will be necessary only during severe draught conditions. The estimated industrial water usage in the city is 60,000 cubic meters per day, which is relatively low.

The cost for water is listed in Table 2 and reflects a progressive scale. The more water that is used, the higher the cost. This is an unusal rate structure, but a desirable one as it discourages wastage of water while making it readily available to the poor at a low cost.

Water is supplied both directly to individual dwellings and also to community taps (Table 3). All water is metered. The community taps are operated by local residences 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.

The one problem in water supply is that of quality. The river upstream from Seoul is of excellent quality as indicated in Table 4. However, wastewaters running from the city are presently discharged untreated into the Han River and as it flows through the city it becomes grossly polluted. The water intakes for three water treatment plants are located downstream from significant sources of pollution and difficulties have been experienced in treating the water to an adequate degree. 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 of very poor quality. When the treatment plant was visited, 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

TABLE 1

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		75	
1961	2.58	290	56	201
1970	5.54	1110	86	234
1976	7.15	2280	92	347
1981	7.50	3080	95	432

TABLE 2

CHARGES FOR WATER USE

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
Public Institution:		10

TABLE 3

WATER SUPPLY FACILITIES

(Seoul Statistical Yearbook, 1971)

Year	Population (Thousands)	Households (Thousands)	Percent Serviced		Number of Faucets (Thousands)		
			Population	Households	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

TABLE 4

QUALITY CHARACTERISTICS OF HAN RIVER WATER UPSTREAM FROM SEOUL

THIS TABLE WILL BE COMPLETED LATER

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. Nevertheless, this is a somewhat dangerous situation as failure to treat the water adequately could lead to large scale introduction of pathogenic organisms into the distribution system and widespread disease. Such a case occurred at New Delhi, India in 1955-56 and resulted in about 30,000 cases of infectious hepatitis. In this case adequate controls on chlorination were not available. However, in the City of Seoul control testing appeared adequate and likelihood of such a condition developing would not appear great. However, constant vigilance must be maintained. In addition, a water of high quality is not possible even after normal treatment. It was reported that taste and odors occurred in the water but because methods for removal were expensive, no attempts were made to remove these aesthetically unpleasing materials. There was also some indications that the turbidity in the water supply was high at times and could not adequately be removed. This condition probably results from high turbidity in the river rather than from pollution from the city.

Concern over the quality of the raw water due to pollution was expressed by many, but suggested methods to alleviate this problem were different. Some suggested the best remedial method would be treatment of the sewage being discharged to the river. A new sewage treatment plant was under construction on the Chong Gye Chun River to help in this respect. Other proposed plans were to extend the water intakes upstream above the points of pollution. Opposition to this plan were given by those that felt this would delay plans for treatment of the sewage as it would remove the incentive to do so. In any event, the problems resulting from pollution to the water supply were well recognized and discussions over methods for pollution control were being carried on in many quarters. It can probably be expected that at some time in the future, when economic conditions permit, upstream intakes for water supply, and adequate wastewater treatment systems will both be developed. In the meantime, methods to relieve present adverse conditions at minimum costs are being sought.

WASTEWATER DISPOSAL

A. Night Soil

In the City of Seoul, the dry method for collection of human excreta is practiced. The "night soil" is collected about once each month from each dwelling by men who scope the night soil from latrines, place it in buckets and carry it to trucks. The average quantity of night soil produced is about 1.1 liters per capita per day and each truck for its removal has a capacity of about 4,500 liters. During March most of the collected night soil was being distributed to farms outside of Seoul for use as fertilizer. The night soil was discharged into pits from which the farm workers took it to spread on the soil. During the remainder of the year, when the demand for fertilizer is not at a peak, the night soil is discharged into pits at disposal sites located three to four miles from the city. Here the night soil ferments and the solids tend to concentrate in a floating mat on the surface of the pit. Workers scrape the solids from the surface and lay it on the banks of the pit to dry. It is then packaged into straw sacks (about the size of burlap bag) and sold for fertilizer. Farmers buy the dried night soil for about 80 won or 20 cents per bag.

When night soil was collected from the household, the homeowner paid for the collection at the rate of about 20 won for a pail full, the pail having about a 10-liter capacity.

The city plans to build four new disposal sites in the future using more modern techniques. There is some realization that the present night soil disposal methods produce public health problems, particularly when untreated wastes are used on crops which are eaten raw. Two highly modern plants for treatment of night soil are being planned. These will use a wet-oxidation method for combustion and are being purchased from a Japanese firm. The method involves pumping air into the waste and then combustion under high temperature and pressure conditions. This will result in the 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 and will require skilled operators for controlling and maintaining the process, judging from experience with similar processes in the United States for sludge disposal. It was indicated that twelve similar plants are in operation at present in Japan.

The directors of night soil disposal in the Cleaning Bureau recognize that the wet combustion method is expensive and are considering other methods for safe treatment and disposal. Most of the methods being considered employ storage and biological decomposition either under aerobic or anaerobic conditions. One of the presently favored methods employs 90 days of fermentation in a 5-meter deep tank followed by dewatering 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, although perhaps they would be operated under more controlled conditions to insure better destruction of pathogenic organisms. This is something which would seem to need evaluation.

One difficulty expressed was in the selection of new disposal sites. None could be found within 20 kilometers of Seoul mainly because of objections by the people living near potential sites. This is a common problem in all countries. It was indicated by the Cleaning Bureau personnel that in Japan an economic inducement was given to get people to accept night soil disposal sites near their home. They felt that something of this nature may be required in Seoul.

The quantities of night soil produced and the present methods of disposal are listed in Table 5. Less than half of the night soil is collected by trucks and either taken to disposal pits or used directly for fertilizer. Another one quarter passes through flush type toilets which discharge to tanks, with the effluent being discharged to streams or sewers. Another one quarter of the night soil is directly discharged into the Han River or otherwise is unaccounted for. Direct discharge into the rivers, streams, or sewers is presently not legal, but is difficult to prevent. Unauthorized discharge of human wastes occurs frequently at night, but evidence that it is done openly was apparent as

TABLE 5

NIGHT SOIL DISPOSAL IN SEOUL

METHODS AND QUANTITIES FOR 1971

Method of Night Soil Disposal	Volume of Night Soil (kiloliters per day)
Flush type toilets with septic tanks:	1570
Regular night soil collection and disposal:	
Disposal Tanks	1545
Direct use as fertilizer	1377
Discharged to Han River:	1178
Other unaccounted for:	476
Total:	6146

several latrines built directly out over the storm drains were in evidence. This testifies to the difficulty which has been experienced historically in efficiently collecting all the night soil from a city by the dry method.

B. Wastewater Collection and Treatment

There are four major drainage basins in the City of Seoul. The Chong Gye Chun Basin includes the greatest area in the city. It contains the centers of government from both the City and Republic of Korea and covers 5,631 Hectars. The Chong Gye Chun River discharges into the Han River at the upstream side of Seoul. 55 percent of the city's water supply is taken downstream from the discharge point. The Han River is a prime recreational asset for bathing and fishing, but because of the pollution brought to the river partially by way of the Chong Gye Chun River, swimming is now prohibited.

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 homes, along the streets, and 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 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, commerical, and industrial purposes. This is a normal evolutionary occurrence. When water is brought to individual homes or made more convenient for use, the demand increases. The resulting wastewater after use must go somewhere and is normally discharged to natural drainage canals or existing storm sewers. 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 500 mg/l. BOD is a measure of the quantity of oxygen used by organisms in decomposition of the wastes. Measured in similar terms, the strength of sewage in the United States is about 200 mg/l BOD, a lower value due in a large degree to the greater per capita water usage.

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 560 parts per million to about 20 parts per million. The plant is to be completed in 1972.

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 might seem strange, but construction of a modern sewer system would be much more expensive than building the treatment facilities only. The future plans are not to build an intercepting sewer to 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. Table 6 represents a summary of analyses for the Han River. The data is quite limited and was not coupled with flow data, which is necessary to obtain a better understanding of the extent of the pollution. However, measurements of river flow could be obtained from other sources and calculations of the population equivalent of the BOD contained in the Han River were made. These calculations suggest that the quantity of wastes contained in the Han River are equivalent to the wastes from a population of about 5 million. This approximates the population of the City of Seoul. It also suggests that night

TABLE 6

POLLUTION CHARACTERISTICS OF HAN RIVER AT FIRST HAN RIVER BRIDGE IN SEOUL

(Hyo San Kim, Jae Eun Won, Jun Jae Woo, "A Study on the Water Pollution of the Han River and Other Streams in Seoul Area.")

	Date of Sampling (1970)					
	2/11	5/18	6/24	9/26	11/24	12/23
Temperature °C	7.0	18.0	26.0	21.0	5.0	4.0
pH	6.8	6.8	6.8	7.0	7.2	7.3
Alkalinity (mg/l)	105	55	58	56	52	31
Dissolved Oxygen:						
mg/l	6.2	4.9	4.7	5.0	6.4	6.0
% Sat.	51	54	58	55	50	45
BOD (mg/l)	38	40	40	46	42	31
NH_3-N (mg/l)	4.8	5.1	2.8	3.0	2.6	3.2
MPN per ml			54,000		100	180

soil collection and disposal is relatively of 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 suggest 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.

The sequence of developments in the water and water pollution control in the City of Seoul are typical of the evolution which occurs in most cities. One of the first necessities for people when they move to the city is for water. When water is supplied in sufficient quantities for cleaning and household uses, then large quantities of wastewater result. Wastewaters must be disposed in some fashion and the only reasonable way seems to be by discharge into the natural drainage canals. The wastewater eventually reaches the rivers which then become grossly polluted. The wastes are transferred from the housholds to the rivers. It is quite general that water is supplied to a city without considering the fate of the wastewaters which will result. It would seem evident that planning is necessary to coordinate the supplying of water and the removal of it once it is used. Such planning has not occurred in the City of Seoul with the result that construction of a good sewer system will be extremely difficult and costly. Perhaps other methods of disposal will need to be sought.

Industrial Wastes

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 little 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 perhpas quite unusual for a city of this size and should not be considered as typical for all cities.

PUBLIC HEALTH PROBLEMS

A major environmental concern about methods of water supply and waste disposal is the affect on public health. Good data which might reflect on these relationships is difficult to obtain. Diseases which can be transmitted by water might also be transmitted by other means such as through food or personal contact. With this limiation in mind, there are some statistics which tend to suggest the existence of public health problems associated with contaminated water supplies or unsanitary methods of waste disposal.

Night soil collection and use for fertilizer on crops has apparently led to widespread parasitic infection among the Korean population. The Korean booklet on "Major Policies and Programmes of the Ministry of Health and Social Affairs," for 1970 states that 90 percent of the people in Korea are inflicted with parasitic diseases. The estimated distribution of parasitic organisms in the population is listed in Table 7. A large percentage of the people have multiple parasitic infections. Such infections can weaken individuals, make them less efficient in their work, reduce energy, and reduce the efficiency by which food is digested and used by the body. Diseases of this type result in serious loss to the country as it greatly reduces the productivity and efficiency of the people.

The major cause of parasitic infections is believed to be the use of night soil for fertilizer, the consumption of raw vegetables fertilized with night soil, and poor environmental sanitation. Night soil contains the eggs of parasites. When vegetables are fertilized by night soil and then are eaten raw, the eggs enter the digestive system to reinfect the consumer. This problem is recognized by the Korean Government and plans were indicated to establish so-called parasite free vegetable centers, making use of chemical fertilizers instead of night soil. Some of these centers can be seen around the City of Seoul. There was no data available, however, to indicate whether those living in Seoul were more or less affected by this problem than the rural people.

Another serious waterborne disease is typhoid fever, although it can also be transmitted through food. Trends in the morbidity rate of

TABLE 7

INCIDENCE OF PARASITIC DISEASE AMONGST KOREAN POPULATION

["Major Policies on Health and Social Affairs," Ministry of Health and Social Affairs, Republic of Korea (1968-1970).]

Disease or Causitive Agent	Percent of Population Infected
Ascaris lumbricoides	80
Trichocephalus trichiurus (whip worm)	80
Enterobiasis	40
Ancyclostoma Divodenal (hook worm)	20
Trichostronglus Orientalis	20
Brugia Maltagi	2
Chlonochiosis Sinensis	15
Paragonimiasis Westermani	5
Taenia Sp. (tape worm)	5
Amebic dysentery	10
Malaria	1

typhoid fever in the country and in the special City of Seoul are listed in Table 8. These statistics suggest that the typhoid rate in Seoul might be lower than that for the country as a whole. However, it is difficult to judge whether the data is comparable since it was obtained from different sources which might have used different methods for gathering and analysis of data. The major source of typhoid fever in Korea was believed to be poor environmental sanitation and contaminated water supply. The 1969 and 1970 reports suggest that defective water supply systems are the major cause.

In 1963 there was an outbreak of cholera (also commonly transmitted by water). Another epidemic was reported in 1969 which produced 1,538 cases and 137 deaths. At that time in Seoul the number of cases of cholera was 43 with 1 death. Again, the incident rate appears to be less in Seoul than in the country as a whole. Thus, rapid urbanization has not appeared to adversely affect the incidences of disease normally associated with water supply and wastewater disposal. If anything, the data suggest that disease rates are reduced by the more modern techniques for treatment of water supply and for disposing of wastes. In addition, better health services are probably a major factor in reducing the seriousness of these diseases.

In viewing night soil collection, it was obvious that this is a difficult thing to do in a sanitary way. The collection buckets were generally filled near to the brim with night soil. Obviously the home owners would wish this as they must pay a certain price for each bucket of waste collected. Buckets were suspended from the ends of a pole carried on the shoulder of the collecter as he walked from the house to the waiting truck, the night soil splashed on to the walkways as the buckets swung to and fro. When a potentially dangerous operation becomes commonplace, people tend to forget the nature of the dangers and become less cautious. This was readily apparent when a night soil collector with his bucket passed through a crowd of school children. Several almost bumped into the buckets, apparently with little concern for what they contained.

No data was available on the incidence of disease among the night

TABLE 8

INCIDENCE OF TYPHOID FEVER AND CHOLERA IN KOREA AND SEOUL

	Typhoid Fever Cases				Cholera Cases			
	Total Cases		Cases per 100,000		Total Cases		Cases per 100,000	
Year	Korea	Seoul	Korea	Seoul	Korea	Seoul	Korea	Seoul
1966	3563	-	12.2	-				
1967	4230	391	14.2	9.8				
1968	3744	265	12.4	6.1				
1969	5404	864	17.6	18.0	1538	43	5	0.8
1970	4221	840	13.5	15.2				
1971		729						

soil collectors. However, some idea of the potential dangers may be obtained from a study made by the Central Public Health Engineering Research Institute in India of workers on farms where sewage was used for irrigation. The study indicated that the farmworkers were very much affected by gastro-intestinal diseases, anemia, respiratory diseases, and skin conditions. The reported data are shown in Table 9 for the test group of farmworkers and a control group of non-farm workers. While this data is for a different type of human waste disposal than practiced in Korea, it is nevertheless suggestive of the public health dangers of working with untreated wastes.

Another obvious feature of the night soil disposal system in Seoul was that a large portion of the night soil could not be collected and in some manner reached the streams draining from the city into the Han River. Historically, night soil collection has been found not to be 100 percent efficient, and regardless of ordinances prohibiting the introduction of night soil into drains, a significant fraction of human wastes always seems to reach the sewers for discharge to receiving waters. Also, when water is supplied to the people in adequate quantities to satisfy their needs for cleanliness, cooking, and other sanitary purposes, the wastewater that results is heavily contaminated. The open ditches and conduits which carry these wastewaters present a public health problem because of ready access to the wastewater by the people. In some streams where pollution was obviously present, women could be observed washing clothes. This practice appeared to be quite minimal, however, especially in the more grossly polluted streams.

Even with an efficient program of night soil collection, wastewater reaching the streams resulted in such pollution of the Han River that swimming has been prohibited for several years. This is unfortunate as the Han River could furnish a major recreational outlet for the people if developed properly.

Another problem from wastewater discharge to the river is the possible contamination of water supplies. The major water intakes are located downstream from sources of pollution and this has led to obvious difficulties in providing a good quality water. There was no

TABLE 9

<u>TABLE WILL BE COMPLETED LATER</u>

evidence that the water was not being adequately treated to protect public health, but very close control over the system is necessary under such circumstances.

Another adverse environmental effect of the pollution is its effect on fish life, recreation, and esthetic factors. The oxygen resources in the river at Seoul and upstream seemed sufficient for propagation of fish life. The gross pollution downstream from the city would probably prevent the entrance of migratory fish which may live in the sea, but spawn in freshwaters. No evidence that such species are important economically in the Seoul area was found. Since the Han River downstream from Seoul passes along the border between North Korea and The Republic of Korea, little concern over the quality of river downstream for Seoul was noted or could be expected. This is a special consideration which one must have when viewing the water pollution problem in Seoul.

ALTERNATIVES

Water Supply

The nature of water supply and waste disposal problems in growing cities are little different today than they have been for centuries. There seems to be a reasonable correlation between the level of development of a water supply system in terms of convenience for use and degree of purifaction, and the level of income of the people. In the more impoverished nations with per capita incomes of less thant $100, money is needed for basic necessities such as food, clothing, and shelter. People at this level are primarily concerned with obtaining a sufficient quantity of water to satisfy body needs, whether contaminated or uncontaminated. Here, hand carrying from open and usually contaminated wells may be the only alternative available. As income rises from $100 to $300 per capita per year, then protected water supplies which are pumped to community taps dispersed throughout the city or village are within economic reach. Such systems afford much better protection from contamination. Also when piped close to the home so that the supplies are more conveniently available, demand increases from about 5 gallons per capita per day to about 20 gallons per capita per day. If the supply is insufficient to meet this demand, then pressure drops result in the system, water becomes unavailable when needed, and a potential exists for the drawing of polluted surrounding waters into the water mains. Thus, before a system of this type is devised, an adequate supply to meet the increased demand should be insured.

As per capita income increases to the upper portion of the $100 to $300 range, a significant portion of the population will wish to pay for having water taps in their homes. This again results in a greater demand for water, perhaps increasing to 60-100 gallons per capita per day. Again, when changes of this type are anticipated, then increased demands should be expected and provided for if contamination is to be avoided. Adequate supply provision has not been the case in certain major cities throughout India, with the result that water is available for only a few hours each day and a great risk of pipeline contamination is assumed. A similar situation occurred in Seoul up until recently, but a sufficient supply to satisfy the current demand appears to have been achieved.

Once water is supplied to the homes and an increased demand for water exists, then a new problem results. That is the creation of large volumes of wastewater which is usually discharged into ditches, ponds, streams or whatever natural drainage ways there may be. The highly polluted water running from households tends to contaminate rivers, well supplies, and streams, eventually leading to the necessity for waste treatment if significant pollutional problems are to be avoided. Laws prohibiting the discharge of body wastes into these wastewaters have been attempted for centuries without success. For this reason there is little reason to believe that a reasonable enforcement system could be established to accomplish the efficient and complete segragation of such wastes from the wastewater running from the cities.

At the 1971 workshop on "Water in Man's Life in India" the question was asked whether there is an alternative to the water carriage system for waste disposal. Presently, the answer appears to be no. Collection of human wastes by the dry method is unsanitary and it appears this will remain to be the case unless there exists a willingness to pay the much higher costs which would be required for sanitary collection and disposal. Treatment of the collected wastes to prevent public health problems is also expensive and for this reason it will probably not be done adequately in a developing country. In addition, such systems are very inefficient and a large fraction of the body wastes can be expected to reach the wastewater systems, especially if a charge is made for night soil collection as it is in Seoul. In addition, street washings, cooking wastes, and waste from cleaning will reach the wastewater carriage system and in itself will result in gross contamination of rivers and streams. Thus once water is supplied to a city, the wastewater disposal problem must be faced. Adequate treatment requires a higher level of per capita income if it is to be adequately achieved.

Eventually as income approaches the level of $800 per capita per year, an adequate system of collection and interceptor sewers can be built to transport the wastes from the households to a point downstream from the city.

When per capita income rises to the range of $1,000 to $5,000 per capita per year, then water supply and wastewater disposal system of the more modern type will come into evidence. This generally consists of pipelines reaching upstream to uncontaminated water supply sources. Waste disposal systems consisting of a system of intercepting sewers to transport the wastes to points below the city, followed by adequate treatment by primary and secondary procedures, prior to discharge to rivers and streams. The cost for a wastewater collection and disposal system is higher than that for a water supply system and so is generally built last. The above evolutionary development of water supply and wastewater disposal system is suggestive of alternatives which the developing cities might follow. When incomes are low, most expedient methods of obtaining water supply must be sought. If incomes are not expected to rise rapidly, a fully safe and adequate water supply and wastewater disposal system may be out of the question and interim procedures must be maintained.

Recognizing the close connection between water pollution problems and the development of an adequate water supply, and also recognizing the relationship between convenience of water supply and demand for water, the following practices seem evident.

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 increased demand which will result 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 wastewaters which will be generated, can be assured. Perhaps this means initially the provision of drainage facilities from the houses to the drainage canals. It might also mean provision of some type of inter-connecting interceptor sewer or canal system to carry the wastes below the city, or else 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, and may be more expensive than a gravity sewer system, if it had been planned for while the city was developing.

It is perhaps unrealistic to expect that a developing country will wish to waste many years to develop a good water supply system because they lack adequate funds to provide for an adequate wastewater carriage and treatment system. This does not decrease the desirability of establishing plans for the future handling of wastewaters. Land right of ways can be acquired. A general plan for eventual collection and disposal of the waste can be developed, and portions of the system which will minimize the adverse effects of pollution at minimum cost can be constructed.

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. In Seoul the level of income has risen to the point where an adequate supply of water is available and a water pollution problem has resulted. An adequate sytem of collecting sewers has not yet been established, but a decision has been made to treat a portion of the waste being discharged from the city. Treatment facilities are much less expensive than the collection system. There is justification for building the treatment facilities at this point in time rather than developing a better sewer system which would only hasten the speed by which the wastewaters reach the Han River, and would do little to remove the pollutional load. A decision has been made to build a series of treatment plants to treat the wastewater running from each of the major drainage basins of the city. This may prove to be less expensive than an intercepting sewer which collects the wastes from each of the basins for treatment at a single plant. A disadvantage of this system is that treatment is not 100 percent efficient and some portion of the wastewater will reach the river upstream from the water supply intakes. It can be expected that in the future, however, a water supply conduit can be built to obtain water upstream from the city before it becomes polluted. Aqueducts for water supply can perhaps be built cheaper than sewers, and this may be the best alternative for the future.

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.

Another problem which does not appear to be serious in Seoul, is the discharge of industrial wastes. Fortunately, the industrial complex in Seoul has been developed so that its wastes are discharged downstream from the city. Whether by accident or design, this has helped to minimize the seriousness of the pollution problem and might serve as a model for development in other growing cities. Developing countries usually cannot afford to hamper industrial growth, but by proper location the impact of the pollution which will result can be minimized. However, it would be wise in zoning and in establishing industrial ordinances, that provisions be made in terms of space for construction of pollution control facilities whenever this becomes economically feasible or otherwise necessary.

Whenever cities develop, priorities are usually first for supplying a quantity of water sufficient only to satisfy the basic bodily needs. Second priorities are for the 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, then cities can develop in a better planned and less costly way.

One of the requirements for adequate planning is a good data base. Usually, little effort is put into the gathering of data, perhaps because description of problems coupled with financial inability to solve them can be a source of discontent among people. It is obvious, that in many countries data which emphasizes such problems is not readily made available to the public even though it may be collected. Efforts to repress data of this type is apparent. However, such data must be made available to those who must do the planning, if planning is to be done in an efficient manner.

The collection of data and planning for the future assumes that one has adequately trained personnel and technical facilities to carry out these functions. One of the early tasks which can be taken in a developing country is the education of a core of individuals with adequate training in water supply and pollution control so that they can analyze existing problems and perform planning adequately. A contrast here exists between India and Korea. In India, a high level of public health engineering programs are in evidence at several universities with excellent staffs. The Central Public Health Engineering Research Institutein Nagpur is carrying on important research which is applicable to the problems in India. Research programs are also carried on at several universities. A good collection of data on the problems in India is also available. The major difficulty in India, however, is lack of sufficient income to take significant steps in building adequate water supply and water pollution control facilities.

In Korea, a lack of programs for the training of engineers in this area was apparent. The universities are not well supported for the training of graduates and an understanding of the need here does not seem to be well understood by the public officials. Funds for research in this area at the universities seems to be nonexistent. This is a deficiency which is badly in need of correction.

In addition, there appears to be no serious research efforts either by independent governmental research laboratories or by the universities. Again, funds have not been provided for this function. Dependence on outside agencies for advise 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 a dependence will result in the establishment of inefficient systems. Those within a country understand their own problems better, and can view them carefully over extended periods of time. They will have a better understanding of the types of systems which can be built and operated in the country with some chance of success. Outside firms are generally inclined to promote high level technologies which are generally inappropriate to developing countries. If a country expects to develop rapidly and efficiently, then it should begin to establish internal manpower resources which are so necessary for this end.