A Comparative Study of Metropolitan Water Supply and Drainage Systems in Developed and Developing Countries — The Cases of Tokyo, Mexico City, Paris and São Paulo —

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Abstract

In this paper, the author examines the water supply and drainage systems of Tokyo, Mexico City, Paris and São Paulo. Through a comparison of the former two cities, we recognize the difference between an advanced city and a primate city in a developing country. To this schema, Paris, another advanced city, and São Paulo, one more primate city in a developing country, are added, to give an extra dimension to the observation.

As the main point of view, an analysis of the historical development of the water supply and drainage systems is done. Then, the diffusion of the systems and their maintenance in terms of working order are examined in each city.

In conclusion, the author has placed these four cases in the schema of advanced cities and primate cities of developing countries. But the meaning of “advanced” is expressed in a different way in the cases of Tokyo and Paris, and on the other hand, Mexico City and São Paulo have their own ways of development, although they show the same kinds of problems, which are characteristic of primate cities in developing countries.

The process of development represents the history of the necessity of their installations, which appear as a result of the convergence of social conditions with physical ones.

Key words: water supply, drainage, primate city, developing country, advanced county, diffusion rate.

I. INTRODUCTION AND METHOD

Cities have required a water supply since ancient times as seen in the ancient cities of Mohenjo-Daro, Athens, Rome, etc. The water supplied is, after use, carried away in the drainage system to form the water circulation of the city, and the drained water from one place might be used repeatedly in others. Thus, there is an inseparable relationship between the water supply and drainage systems in a city. But there are few geographical studies that treat these two subjects as a set (Fox, 1965; Takagi, 1976; Arai, T., S. Shindo, A. Ichikawa and A. Yoshikoshi (1987); Hagiwara, 1989).

Tokyo and Mexico City are two of the biggest cities of the world in metropolitan population. We can see that these two cities have some common points; for example, both cities, based on their respective cultures, were already large and prosperous before the arrival of any European cultural influences. For both, a considerable degree of European-style modernization began at almost the same time: the middle to late 19th century. But their physical and social environments are quite different; Tokyo is situated on a “vast (by Japanese standards)” plain with several rivers, of which the Tone is the most important, while in contrast, there are few significant rivers on the highland basin where Mexico City is located. Tokyo is said to be one of the world’s economic and cultural centers and, on the other hand, Mexico City is a representative city suffering from urban problems, where population growth rates have far outstripped the growth of the infrastructure (Fig. 1).

In the following chapter, the author will point out some differences between Tokyo and Mexico City concerning the water supply and drainage

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Figure 1. Population and water supply, Tokyo and Mexico City

(3) Man-Water Relationships in Metropolitan Mexico (FOX, 1965).

Notes: (a) Mean water supply by the Bureau of Waterworks, Tokyo Metropolitan Government, for the 23 Wards, including 24 cities and towns within the Metropolis which were incorporated, from 1973 to 1977, to the Bureau’s operation.
(b) Mean water supply for the Federal District.

systems. After that, he will proceed to descriptions of Paris as a case of a more advanced city as far as these infrastructures are concerned and of São Paulo, another Latin American metropolis suffering from the same kinds of urban problems as Mexico City.

Tokyo began its remarkable modernization in the late 19th century, adopting to a large extent the Occidental culture, and it has been influenced also from the example of Paris, to become the center of an advanced country today. In contrast, Mexico City is said to be a typical example of primate city in a developing country, where we find a series of serious urban problems principally caused by a greatly increasing population (HOSONO, 1985). So, too, is São Paulo, although its primacy index of population in Brazil is not so high (NAKAGAWA, 1988) and both Mexico and Brazil are considerably industrialized countries today as the term NIES indicates.

Although not numerous, the comparative method in urban geography seems to explain the situations concerned relatively clearly. Applying almost the same items of comparison to two mutually different cities, it is possible to identi-

Figure 2. Edo (Tokyo) before the Edo Era

Figure 3. Water supply system by the josui aqueducts, Edo
Source: Meiji-izum Nihon-dobokushi (History of Japanese Civil Engineering until the Meiji Era).

II. DEVELOPMENT OF WATER SUPPLY AND DRAINAGE SYSTEMS OF THE AREAS EXAMINED

1. Tokyo

The establishment of Edo dates back to 1457 when the feudal warrior Ota Dokan constructed his home castle there. Its magnificent history as a large city in the modern age came after 1590 when the feudal warrior lord Tokugawa Ieyasu moved into Edo and began constructing a large jokamachi (castle town). Before his entrance into Edo, a very small agglomeration of houses might have existed in the present-day downtown area and a few farmhouses were dispersed in the surrounding area (Naito, 1972). Quite different from most of the then existing Japanese cities and towns, which had been almost exclusively located on alluvial lowlands, the urban plan of Edo was to be laid out to expand over both alluvial lowlands and diluvial (hilly) uplands. At that time, what are more advanced or less developed in the relative scale (Masai and Philbrick, 1963; Masai, 1977; Brunn and Williams, 1983; Berque, 1987). The other set of two examples, Paris and São Paulo, will be added to this comparative study, so that rather more dimensional, objective and conceptualized conclusions as to the developmental stage of water supply and drainage systems can be drawn.

Photo 1. Senkawa-josui: a tributary of the Tamagawa-josui. It had been abandoned as an aqueduct, and was left without running water. But in 1989, this josui was redeveloped as an important part of the built-up environment in the city, receiving treated waste water from the nearby treatment plant.
Photo: Bureau of Sewerage Works, TMG.
time the coastline was much further inland than today: the hilly site of the castle was at first just by the shore of the Hibiya Inlet (Fig. 2).

**ToKUGAWA Ieyasu** then began to exploit the area so that a large number of people could live there; he had creeks dug in order to drain water from marshland and lowlands, and filled in the inlet.

In the southern part of early Edo, water that had accumulated in Tameike in Akasaka was drawn to the fronts or backs of houses through the use of narrow covered ditches, and in the northeastern part, water from the Koishikawa River was drawn downtown. This aqueduct later became the Kanda-*josui* (aqueduct), and a network of wooden pipelines was developed throughout the townsfolk's lowland area. As for the southeastern area, which consisted mainly of residential heights, water from the Tama River was drawn in 1654 through a 43 km long aqueduct, which had a 92 m height difference between its starting and ending points. By the middle of the 17th century, the basic water supply system in Edo had been established mainly with the Kanda-*josui* in the northeastern downtown lowlands and the Tamagawa-*josui* in the southwestern heights (Fig. 3). Later, wells were also exploited.

On the other hand, rain and city waste water was generally drained into the moats which had been constructed for the purpose of defending the castle, or into the canals which had been dug for ship transportation. In spite of its large population (the population of Edo reached one million without experiencing the Industrial Revolution) and a high population density (60,000 persons/km² in many townsfolk quarters), Edo's hygienic condition is said to have been kept relatively clean, partly because human excrement was not dumped into water systems but was transported to the nearby farmlands (KAWAZOE, 1982).

**Since the Meiji Era**

At the time of the Meiji Restoration in 1868, Edo was renamed Tokyo, and this city became the new capital of Japan. Tokyo's population, which had decreased considerably owing to this revolution, soon recovered and continued to increase (Fig. 1). However, a problem concerning...
drinking water arose in the early Meiji era after it had been neglected during the disorderly period of the Meiji Restoration. The Meiji government then initiated a plan for a modern water supply system for Tokyo after asking Dutch, English, German and Belgian engineers for their opinions (SATO, 1960). The plan was partially completed in 1898. The source of this first water supply system was the Tama River, which meant that the original aqueduct of the Tamagawa-josui was replaced, and water from the Edo and Sagami Rivers was added to the Tokyo water supply system in 1926 and 1956, respectively.

After the Meiji Restoration, Tokyo suffered from two disasters, the Great Kanto Earthquake (1923) and World War II air raids (1945). Tokyo has tried to install sufficient waterworks by taking the opportunities of city planning. However, the postwar recovery and the rapid economic growth in the 1960’s resulted in a chronic water shortage, of which that of 1964 was the severest. Finally, in 1965, drawing water from the main stream of the Tone River, one of the largest watersheds in Japan, was realized in order to solve this problem. Today, approximately three-quarters of Tokyo’s water supply is dependent

Figure 5. Ground subsidence in Tokyo and Mexico City

Source: (1) Tokyo no Jiban (The Ground of Tokyo), Institute of Civil Engineering, TMG, 1977.
(3) Memoria de las Obras del Sistema de Drenaje Profundo, 1975.
(4) As for Figure 1. (2).
Many factories existed in the eastern alluvial lowlands, where a considerable degree of ground subsidence occurred as a result of excessive pumping of groundwater (Fig. 5). As a solution to this problem, two industrial water supply lines were constructed in 1965 and 1971 for the industries.

Regarding drainage, a considerable degree of construction of drainage facilities was begun in 1913, much later than the water supply works. A characteristic of Tokyo is that, from the beginning, as a treatment plant has been installed, drainage has been done by combining rain water with waste water. Tokyo now has 10 treatment divisions for its 23 Wards (Tokyo Proper), with the topography of the respective divisions considered (Fig. 6). A point to be noted is that, historically, protection of the city from heavy rains was the main purpose of their construction, but the preservation of the surrounding public water was declared a goal in 1970 when the problem of pollution reached a high point.

2. Mexico City

The predecessor of present-day Mexico City was Tenochtitlan, capital of the Aztec empire. It dates back to 1325 when a vagabond barbarian tribe named the Azteca settled on an island in Lake Texcoco (Fig. 7), an inland lake without natural surface drainage outlets.

Aztec Era

In 1376, the first Aztec emperor came to the throne, and this city-nation conquered its neighbors or formed alliances with them to become an enormous empire. Immediately before the Spanish conquest, the area of Tenochtitlan was 10 km² to 13 km² or so, and the population was a little less than 80,000 to more than 100,000, according to different sources (Villegas, 1975; Yamada, 1983).

The relationship that the inhabitants of ancient Mexico City had with water involves two paradoxical aspects; theirs was the task of getting water, which was scarce, and yet protecting the city from overabundant water or floods. This paradoxical relationship began at the onset when the Aztec settled on the island of the Mexican highland basin.

There was a fountain for drinking use in the center of the island, but as water was available in limited areas of the island, aqueducts (dike ways) were constructed across the lake to draw water from the west (Chapultepec) and the south (Coyoacán).

The city was surrounded by shallow brackish lake water. New land was slowly added by a floating plant called chinampa, whose roots reached the lake bed. There were many canals for ship transportation, and waste water from the city was drained into them. Public lavatories were installed in each road, and human excrement was transported to fields. Floods were frequent as a result of a rise in the lake water surface level, and so a 16 km long flood protection dike was constructed in the lake to the east of the island in the middle of the 15th century.

Since the colonial era

In 1521, Tenochtitlan was conquered by the Spanish conquistadores lead by Hernán Cortés. They destroyed the empire's capital and constructed Mexico City in its place as the new colonial capital. Following the colonization by the Spanish, the population of the city increased slightly to reach 100,000 by the end of the 17th century. Eventually, this Spanish colony established its independence in 1821, and a remarkable increase in population appeared with an industrialization movement after the Mexican Revolution (1910–17) (Fig. 1).

Since the Mexico City Olympics (1968), the
The population of Greater Mexico City has doubled to about 17 million in 1984. Today a substantial portion of Mexico City (urban area) extends from the northern part of the Federal District outward into the State of Mexico.

During the first part of the Spanish colonial era, there were no radical changes in the water supply and drainage methods from what had been employed during the Aztec Era. First, a Roman-type aqueduct was constructed from Chapultepec. Besides the water being drawn through the aqueduct, shallow groundwater began to be drawn through wells. But this caused ground subsidence around the center of the city. In this century, water sources were sought from many directions, and deep groundwater was also exploited. As a result, a more considerable amount of ground subsidence occurred (Fig. 5). In 1951, water from outside the Mexican Basin (i.e., shallow groundwater along the Lerma River) was drawn for the first time, and since then, this has been one of the main sources of water for Mexico City (Fig. 8). In 1982, drawing water from the Cutzamala River, still farther than the Lerma River, was undertaken, and now there are some plans for drawing water from remote areas below Mexico City’s level (around 2,240 m) by pumping.

Moreover, measures for flood control continued to be undertaken after the colonization. As an important occurrence, the first drainage outlet to the north from the inland Mexican Basin was completed from the 17th to 18th century. Since then, the water area of Lake Texcoco has shrunk considerably and, as a result, hygienic problems have repeatedly occurred; the dried-up lake bed has become the source of sand storms.

From the 18th to 19th century, Mexico City continued to be subjected to floods; it was a city with hygienic problems. In 1886, a second outlet to the north was constructed, and in 1900, the Gran Canal del Desagüe (today’s most important drainage channel) (Photo 2), which was connected to this outlet, was completed.

Today, water from Mexico City is drained concentratedly northward through the two main drainage lines (Fig. 9). In addition, since 1975, the Deep Drainage (Drenaje Profundo) has been brought into operation during the rainy season when rains occasionally fall quite heavily. The Deep Drainage was installed to drain water from Mexico City to the north out of the basin without the need of pumping.

3. Contrast of the two cities

The annual precipitation in Tokyo is about 1,500 mm and that of Mexico City is just about half this figure, and there is a clear difference between the rainy and dry seasons in the latter city. Regarding geomorphology, Tokyo faces Tokyo Bay, or the sea, but Mexico City has no natural outlet of surface water from the basin. In addition to these physical conditions which have not been so favorable for Mexico City as far as water supply and drainage are concerned, this city has been suffering from a population explosion in recent years, so that not only waterworks and drainage but also many other urban facilities can no longer meet even the minimum demands of the city today.
Figure 8. Water supply system, Mexico City
Source: (1) As for Figure 1. (2). (2) As for Figure 1. (3).

Photo 2. Gran Canal del Desagüe: this open channel is the main drainage outlet of Mexico City. Abundant non-treated waste water is running to the north through this channel, which is protected with fences on both sides in the city area.
Photo: Taken by the author in 1982.
Water supply

Both Tokyo and Mexico City had their own water supply and drainage systems before the arrival of European culture or technology. But the present systems are far developed in comparison with their original form; water sources were to be found in nearer places in earlier days, but today the location of water sources is spread out in many directions and distant, as far as more than 100 km in some cases, from the city area.

The methods of drawing water for these cities show a clear contrast; more than 99% of Tokyo's drinking water consists of surface water, and more than 90% (almost 100% until 1983 when the Cutzamala River became involved) of Mexico City's drinking water comprises groundwater. In Tokyo, recently, there has been some concern surrounding the contamination of sources. Even if potable water is supplied after chloric sterilization, it is said that the danger of cancer caused by the organic chloric compounds is increasing. For example, the Kanamachi Filtration Plant, which furnishes drinking water to the eastern part of Tokyo and draws considerably contaminated water from the Edo River, produces more trihalomethane (organic chloric compounds) than WHO (the World Health Organization) has determined to be the safe standard of one cancer for every 100,000 persons.

In Mexico City, owing to the lack of stability of the water supply, each house has a watertank installed which, through poor maintenance, affects water quality, and this is a possible cause of the great number of diseases of the digestive organs.

The diffusion rates of water supply service are 99.8% for Tokyo (23 Wards, in 1983) and 97% in Mexico City (Federal District, in 1982) (DDF, 1982). When the total amount of water destined for households is divided by the population using it, water consumption is about 200 l/day-person in both cities. Their lifestyles concerning water use are quite different, but it might be supposed that more water is consumed in Tokyo than in Mexico City. A possible reason for this is the fact that the water charges were (until 1982) kept relatively low in the latter city.

In Tokyo, although warnings are issued from time to time regarding possible water shortages, the water supply has been stable in recent years; but in Mexico City, water shortages do occur at the local level, especially during the dry season (from November to April). In the latter city, it is possible to find several houses that depend on one faucet. Consequently, the situation of maintaining the water supply system in working order remains worse in Mexico City compared with Tokyo.

Drainage

The diffusion rates of pipe drainage are 80% in Tokyo (23 Wards, in 1983) and 71% in Mexico City (F.D., in 1982).

Generally speaking, the historically first aim of sewage works is draining rain or waste water to protect the city from floods. The role of treating polluted water has been becoming more important and necessary because of increasing heavy pollution. Polluted water could be cleaned by the natural autotreatment function, but in cases where the pollution charge is heavier than the natural capacity for autotreatment, artificial treatment is necessary to complement this process.

It seems that the basic difference in the drainage methods of these two cities results definitely from the local physical conditions, but they are not, of course, the only factors to determine the whole situation. Tokyo is more advanced in the sense that the diffusion of pipe
drainage is directed toward the preservation of the environment in addition to the role of carrying away waste water, owing to a high density of population and industries in the region. On the other hand, the history concerning Mexico City's draining measures is long; this city has had to deal with concentrated heavy rains, so that a large-capacity drainage system has been installed, and finally, the first stage of the Deep Drainage system was completed in 1975 to overcome the outletless basin conditions unfavorable for drainage. Presently, non-treated waste water has to be drained through two or three (when the Deep Drainage system is included) main drainage lines. A remarkable point of Mexico City besides this large-capacity drainage method is its attitude toward the recycling of waste water, trying to make up for insufficient water resources.

Schema of an advanced city and a primate city in a developing country

When we observe the water supply and drainage systems of these two cities, the clearest schema seems to be rooted in the difference between an advanced city and a primate city in a developing country.

A fact behind the numerical rates of diffusion is that a stable water supply throughout the year cannot be realized in Mexico City, and there is an inequitable distribution of water as 60% of all water is consumed by 3% of the households, while 50% of the households must make do on 5% thereof (ILLICH, 1985). Moreover, the drainage system of Mexico City is simpler or less complete from a standpoint of equipment when compared with Tokyo, which has 10 treatment plants, although the diffusion of pipe drainage in Tokyo is not yet complete (89% in the 23 Wards, 1988). As a background to its attitude toward the treatment of used water, Japan has laws which restrict draining polluted water, with a balance of power between the draining side (industries in the city, etc.) and the drained side (fisheries around the city, etc.) in a clearer way than in Mexico.

Recently the Tokyo Metropolitan Government has been trying to recover artificially some abandoned streams such as Tamagawa-josui and Senkawa-josui (Photo 1) and modify water areas from a visual or environmental point of view, which means that Tokyo has a greater capacity for dealing with an advanced stage of development beyond the minimum requirements.

Both cities are capitals which function as the political, economic and cultural centers of their respective countries. The phenomenon of centralization is seen commonly in both cities, but Mexico City has a negative attitude toward the population coming from the rural regions, as such population influx far exceeds the city's ability to accommodate it.

III. THE CASE OF A MORE ADVANCED CITY: PARIS

The foundation of the city of Paris dates back to 53 B.C. when Caesar occupied the Ile de la Cité, where the people named Parisii were living. With its town walls built from the 12th to 13th century, Paris functioned as a typical medieval city. At the end of the 13th century, this was the largest city in the western Christian world with a population of 100,000. Paris is situated in the center of the Paris Basin, which comprises one fourth of the country in area, and at the lower-middle stream of the River Seine; this location is a favorable factor for both water supply and drainage.

1. Water supply and drainage systems

Roughly until the French Revolution (1789), individual inhabitants got water from wells, fountains and the River Seine. Before the Second French Empire, which started in 1852, a water supply system using water from the River Seine and l'Ourcq Canal had already been constructed, but Paris started to dig deep wells on account of the occurrence of epidemics: Grenelle wells in 1841 and Passy wells in 1861. Since the Second French Empire, the Paris water supply network was developed remarkably, in accordance with the modernizing reconstruction of Paris, led by the prefect of the Department of the Seine Haussmann and the engineer of waterworks Belgrand. Consequently, from the 19th century to the 1930's groundwater sources of good quality were connected to the water supply system from remote areas. Today, surface water is also drawn from upper stream of the River Seine (Fig. 10).
city possesses an original water supply system along the streets fed by the nearby surface water of the Seine and l’Ourcq Canal for washing and other uses. Waterworks for the 20 Wards (arrondissements) of Paris have been operated by two private companies since 1985, the one taking charge of the north side of the Seine and the other the south.

Concerning drainage, the construction of tunnel drainage was begun during the 14th century, and all waste water came to be drained to the Seine within the city area (OKA, 1985). But Haussmann and Belgrand changed the method to draining to the Seine in the northwestern suburbs of Paris. Treatment of waste water through vast sewage farms was also started, and this natural way of treatment became the most successful in the beginning of the present century. Around World War II, the Achère Treatment Plant (Photo 3), which was constructed to take over the sewage farms, was joined to the Paris drainage system to treat waste water artificially with activated mud. Today, this is the main treatment plant for the city’s waste water, to which the 20 Wards and surrounding areas are connected. The sewage farms still continue to be utilized today to complement the Achère plant.

Concerning drainage work for the 20 Wards of Paris, Syndicat Interdépartemental pour l’Assainissement de l’Agglomération Parisienne (S.I.A.A.P.), which is a united organization for Paris and its surrounding 3 departments, is charged with the drainage operations for Greater Paris. This organization possesses two treatment plants besides the Achère plant to serve 8 million inhabitants, including some parts of 4 more surrounding departments (Fig. 11).

2. Comparison of Paris with Tokyo

Paris is one of the most advanced cities as regards modern water supply and drainage systems.

As for water supply, one should take note of the fact that the groundwater sources from remote areas were incorporated into the Paris water supply network at an earlier time. On the other hand, the development of water resources for Tokyo has been pushed outward, owing to chronic water shortages, to maintain a stable water supply by soliciting the cooperation of other prefectures.

The city of Paris has achieved complete diffusion of pipe drainage for the 20 Wards, but the adoption of artificial treatment using activated mud was not necessarily early in comparison with Tokyo. Since then, treatment media for waste water have come to be developed according to necessity. Today, the outlets for drainage are lo-

Figure 10. Water supply system, Paris

(2) Direction des Services Industriels et Commerciaux, la Ville de Paris.
Photo 3. Achère Treatment Plant: a treatment plant which consists of four units (Achère I, II, III and IV) with a capacity of 2,100,000 m³/day. All of the City of Paris (20 Wards) and its surrounding area are connected to this plant, and treated waste water pours into the Seine in the suburbs of Paris.

Photo: S.I.A.A.P.

Located far from the water capturing points for Paris' potable water. Meanwhile, the control of draining polluted water is watched by public inspectors and practiced with the local conditions considered or, case by case, to prevent serious pollution. Nevertheless, it is possible to see that the obviously polluted Seine downstream of Paris, where many factories exist, makes a contrast with the relatively conserved Seine in Paris as well as upstream.

On the other hand, it used to be said that Tokyo’s drainage system was insufficient for a modern metropolis, but it has fast come to catch up with “advanced” standards, in respect of installations at the economical and technological levels.

“Advanced” in the case of Paris does not mean only its complete systems already installed at an early time, but also its provision in taking measures to avoid serious problems. Cities are closely related with their respective countries’ social conditions too: Paris is the center of politics, economy and culture of France, which is the same as Tokyo for Japan. But population concentration on Paris from rural areas has not been so critical for its infrastructure as seen in many large cities in developing countries today. Tokyo has experienced an acute population increase, but Japan’s economy has also grown so that the living standard of the inhabitants has been able to
catch up along with the increasing investments for urban infrastructures. However, the problem of pollution appeared seriously as a result of the recent large-scale industrialization, and a series of laws have been introduced since 1970 to control the industries polluting the public water with waste. It is generally understood that control laws are stricter in Tokyo as compared with the national ones, but a characteristic of the case of Tokyo is that the strict laws were established just after the problem appeared seriously and applied uniformly at the national level. The existence of many factories discharging polluted water into Tokyo’s rivers has caused serious problems indeed, although much has been removed so far. Generally speaking, both Paris and Tokyo can be said to have the common characteristics of “advanced” cities.

IV. ANOTHER CASE OF A PRIMATE CITY IN A DEVELOPING COUNTRY: SÃO PAULO

The city of São Paulo was founded by the Jesuits in 1554. In the late 16th century (around 1582), it was yet a small village of 120 “liberal” inhabitants. A remarkable development took place after the middle 19th century when the cultivation of coffee was introduced to the State of São Paulo (Associação dos Geógrafos Brasileiros, 1958). Situated at about 800m above sea level, São Paulo has no large rivers except the upstream of the River Tiete, but its volume is not sufficient for water supply and drainage for such a big city.

1. Water supply and drainage systems

The first waterworks were begun by a private company to be transferred, later, to the public sector. Today, SABESP (Companhia de Saneamento do Estado de São Paulo) operates both water supply and drainage works for Greater São Paulo except for some surrounding municipalities.

This metropolis draws water from all directions (Fig. 12), but suffers from chronic water short ages at the local level mainly during the summer season when the demand grows. The capacity of installations is not enough to provide a stable supply for all the inhabitants, although the reservoirs are filled up with rainfall. Meanwhile, SABESP surveys several possibilities to increase water resources besides some projects now in process of construction. But it is no longer so easy to develop new water sources for the coming years, since the existing surface water is now already being highly utilized and water source exploitation requires greater cost each time.

Concerning drainage, the city’s waste water is destined for the Tietê or its branches. The River Tietê pours into the River Paraná about 1,000km northwest of São Paulo, but the Tietê is artificially dammed up just downstream of the city, and the dammed water fills in the valley bottom of the River Pinheiros, an upper-stream tributary of the Tietê. It is then, in turn, pumped to the level of Lake Billings, from which water runs down along man-made channels through the coastal mountains, at the same time, generating electricity. This peculiar drainage method was developed by Light & Power, a company with Canadian capital, in the 1920’s to furnish electric energy mainly for the street-cars running in São Paulo. Today, this still comprises the city’s main drainage line (Fig. 13).

The diffusion rate is not so high (58%: Municipality of São Paulo, 1987). The rate of treatment for the drained water is no more than 20%; in other words, less than 20% of the supplied water in quantity. This rate should be raised a great deal so as to improve the crucial environmental situation along the open drainage channels. The authorities are making efforts to install more treatment plants.

2. Comparison of São Paulo with Mexico City

The annual precipitation at São Paulo is about 1,400mm, which is almost twice that for Mexico City. All of the water resources for São Paulo depend on rivers and reservoirs, or surface water, in sharp contrast to the case of Mexico City, where most of the water resources are underground. But a common aspect of these two cities is that the capacity of the installations cannot meet demand sufficiently, although they are furnished with water even from distant areas. A negative phenomenon here arises: the surrounding water-providing areas are suffering from a severe water shortage caused by too much water being taken for these primate cities. Further-
more, in São Paulo, as in the case of Mexico City, there is an obviously inequitable distribution of water, permitting a more stable water supply in the more affluent parts of the city, and also causing, on the other hand, water shortages in certain districts within the urbanized areas (Hagiwara, 1989). This is another phenomenon behind the positive phenomena of the primate cities.

Concerning drainage, each city has its own method of drainage. Mexico City has completed the first stage of the Deep Drainage system as a symbolic installation of drainage for this highland basin city, while, on the other hand, São Paulo’s main drainage system is still dependent on the peculiar system combining the Rivers Tietê and Pinheiros with Lake Billings. Although much has to be done before a complete solution is reached, both devices deserve evaluation.

In both cities there are frequent concentrated heavy rains during the rainy season, and the problem of floods in the lowlands has not yet been solved sufficiently. This phenomenon may be attributed partly to their physical conditions. But another common phenomenon in both cities should be considered here: the pollution of the open channels which receive waste water. This situation appears as a typical characteristic of primate cities in developing countries lacking adequate measures for a large population.

The Mexico City drainage system is equipped with some treatment plants only for the recycling of waste water, and for untreated waste water, the effect of natural autotreatment is functioning to some extent through the drainage lines (Gámez and Herrera, 1981). Although quite insufficient, the São Paulo drainage system is provided with some treatment plants, and is in
process of improvement in treating waste water (Photo 4). These positive aspects of the two Latin American metropolises should be remembered for their present situation as primate cities of developing but considerably industrializing countries.

V. CONCLUSIONS

Tokyo and Mexico City well demonstrate an obvious difference in their physical and social conditions. In the case of Tokyo, we find that its physical conditions are relatively favorable for both water supply and drainage works, and its social conditions have permitted the systems development to arrive at the present situation. Its economic power in particular has made it possible for Tokyo to meet the increasing demand for water by overcoming crucial situations. Its diffusion rate of pipe drainage has been rising by 2% per year recently; this means that the installation of pipe drainage for a population of 170,000 (in 1988) can be realized in one year there.

On the other hand, in the case of Mexico City, we find that its physical conditions are favorable neither for water supply nor for drainage works. But one of the largest cities of the world is located there, and its social conditions have not been able to permit the systems to develop sufficiently for the demand. Juxtaposition of rich and poor, improved and devastated, clean and polluted, and the like apparently exists there.

We have examined, in this study, Paris as an advanced city and São Paulo as a primate city in a developing country with the purpose of seeing further for the fundamental schema of Tokyo and Mexico City today (Table 1). Then, some differences in the meaning of “advanced” are perceived between the cases of Paris and Tokyo, and some common tendencies towards a lack of measures are found between the cases of São Paulo and Mexico City.

It used to be said that Tokyo’s infrastructure, especially drainage, was insufficient for a modern city, but its measures to overcome the problems, such as water pollution, have been undertaken in a relatively short time. And this city is becoming an advanced city in respect of drainage, too; its drainage system involving 10 treatment plants shows the topographical, hydrological, social and areal pattern of Tokyo.

It seems that Mexico City can hardly overcome the problem of a lack of installations in a short period of time, but its attitude toward recycling waste water and the development of the Deep Drainage are noticeable phenomena; its drainage
system also shows the peculiarity of Mexico City. It is recognized, through the observation of the process of development in water supply and drainage systems, that it represents the history of necessity for their installations, which appear as a result of the approach of social attitudes toward physical conditions. Each system has been already destined, to some extent, for a certain direction, but measures to be taken in the future are open to many possibilities, where other cities' examples of positive and negative phenomena might provide suggestions.

In this comparative study, some positive aspects may be noticed rather than negative ones in the Tokyo water supply and drainage systems in comparison with Mexico City. But that doesn’t mean at all that its negative aspects can be ignored.

The dichotomy of “advanced” and “developing” relies on a relative scale. The former could learn from the latter in some cases. Such is the most important question about the case of Tokyo: whether the investment in water supply and drainage works is done in an appropriate direction for ideal water circulation in the city and its surrounding region.

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先進国と開発途上国の巨大都市における上・下水道システムに関する比較研究

——東京、メキシコ市、パリ、およびサンパウロの事例——

萩原 八郎

この小論でとりあげる4都市は、人文・自然環境ともに大きく異なるが、その基本都市施設である給・排水施設に着目し、地域性の理解を比較によって試みた。手順としては、まず東京とメキシコ市について比較・考察し、次に先進国と開発途上国の巨大都市という両者の関係をより多面的に検討するために、先進都市であるパリ、そしてメキシコ市同様に都市問題に苦慮するサンパウロの事例を取りあげ、それぞれ東京、メキシコ市と比較してみた。

その際、主に歴史的発展過程と現在の普及状況について各都市の特徴（長）や問題点を明らかにした。また、上・下水道システムを示す図はできるだけ同一の縮尺で表現し、比較しやすくなった。

その結果、東京とパリの比較では、両者に共通している先進性にもその内容に違いがあることを確認し、一方メキシコ市とサンパウロ市の比較では、それぞれの独自性とともに問題点に共通性が認められた。

これらの比較を通じて、各都市における普及の程度に優劣をつけることは可能であるが、それが本論の目的ではない。地域の自然環境に応じて必要性から作り上げられて現在に至った各都市の上・下水道システムはその地域性を反映するものであるという点を重視し、そのあり方自体には優劣をつけるべきものではなく、むしろそこに見られる優れた点や劣る点について相互に参考とすべきものであろう。その意味で、東京は先進都市であるパリの事例のみならず、開発途上国の巨大都市であるメキシコ市やサンパウロの事例からも参考になる点が少なくないといえる。

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