Integrated Water Resources Management in Urban and Surrounding Areas

Conservation Strategies, Technological Developments, Ecological Values, Socio-Economic Conditions, Institutional Arrangements

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Integrated Water Resources Development And Management in Fukuoka Metropolitan Area

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ABSTRACT Fukuoka Metropolitan Area, a fast growing economic and cultural center in Kyushu, Western Japan, was struck by a severe drought in 1978 resulting in water rationing which lasted for 287 days. The drought showed that the region is vulnerable to water shortage unless development and management of water resources are planned properly to meet growing water demands of population and industry. The Fukuoka Metropolitan Area, however, has a geographical disadvantage and water supply has to rely on small rivers and limited groundwater resources. As a result, the area is always exposed to potential drought, especially small municipalities surrounding the larger Fukuoka City. Limited water resources are now becoming one of the fundamental constraints for appropriate development of the area. In this paper, the present situation of integrated water resources management and a number of unique water resources development projects in Fukuoka Metropolitan Area are reported. Various kinds of measures to restrain the rapid increase of water demand in the area are also presented.

INTRODUCTION

Fukuoka City is located in the northern part of Kyushu, Western Japan, at 33°35′ north and 130°24′ east. The city area is 337 km^2 and the population is 1.25 million. Fukuoka Metropolitan Area consists of Fukuoka City and 20 surrounding municipalities as shown in Fig. 1. The total area is 1,156 km^2 and the total population is 2.02 million as of October, 1991. Residents living in Fukuoka City account for about 62% of the total population in the Metropolitan Area, and in addition, another 8% are concentrated to the city during daytime. The population is, however, increasing constantly. The area has mild weather and climate, and no severe earthquake or flood has ever been recorded. The annual average temperature is 15–16°C and the annual precipitation is approximately 1,800 mm with little snow. Because of seasonal winds, there is both an early summer rain season (June to July) and a typhoon season (September to October).

People living in urbanized areas may feel that water should be supplied as much as

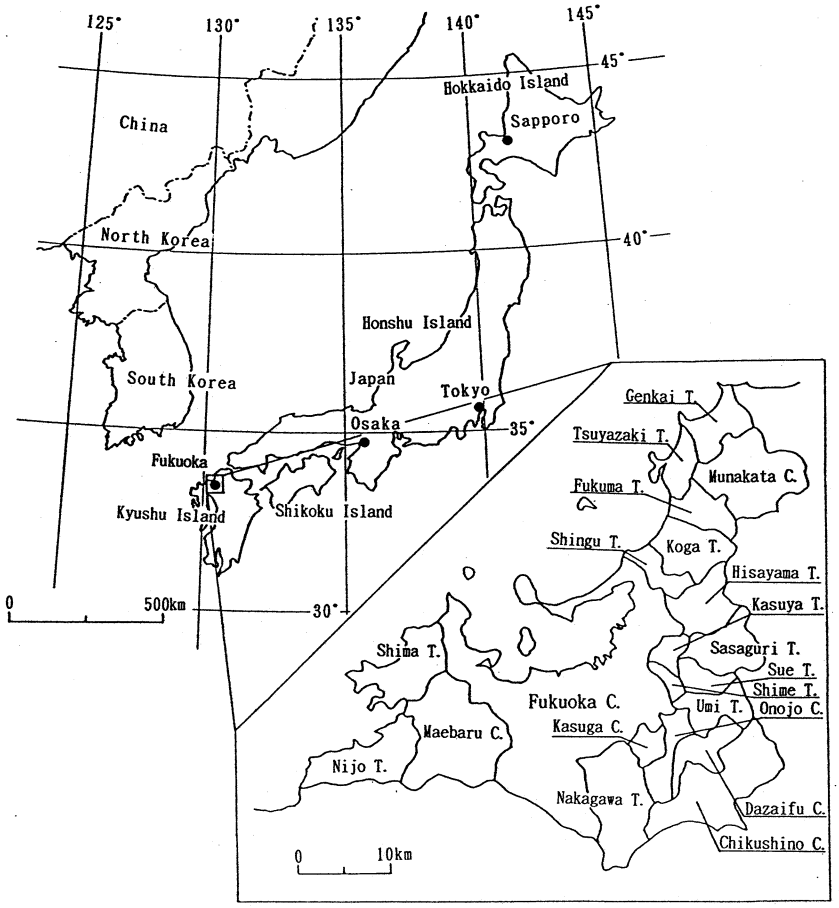

Fig. 1 Location of Fukuoka Metropolitan Area.

they need. This is usually also the case during normal climatic conditions. However, during drought conditions, water rationing may hamper many activities in daily life. Even urban planners are often unaware that water resources are indispensable constraints for appropriate development of a city. The Fukuoka drought happened in 1978. The drought index for this event was 8,160 (% •day) with 19-hour water supply cut per day at the worst. This happened when urban citizens believed that a high water consumption is a barometer of modern city life. The impact was so intense that citizens and authorities suddenly were forced to understand the importance of water, and realized that water is a limited resource. As a result, the drought provided a great challenge for the authorities to develop countermeasures to secure a stable water supply.

Because of the geographical location of the city, water shortage has been experienced many times in the past. In order to cope with this and an increasing demand anticipated in the future, it has been necessary to develop water resources for suburbs as well as areas outside of the city. Also, the authorities are exerting all efforts to promote water conservation in order to make efficient use of the water developed and to maintain a stable water supply.

In the following sections, the present situation of the waterworks in Fukuoka Metropolitan Area and the integrated water resources development and management system including measures to halt the rapid increase of water demand are illustrated.

PRESENT SITUATION ON WATERWORKS

In Japan, water resources planning is designed for a drought with a targeted ten-year return period. Waterworks are governed by public organizations, and on general principles each municipality is responsible for its residents' water supply. By law the waterworks in each municipality have to be operated on a self-paying basis, so that each municipality has to set its own water rate to make ends meet for compensating the water development and managing costs. For example, when a household uses 20 m^3 water a month in Fukuoka Metropolitan Area, the cost varies from 4,510 yen (Tsuyazaki Town) to 1,350 yen (Umi Town) with an areal average of 3,084 yen. In Fukuoka City this cost is 2,018 yen.

The sources of water supply in Fukuoka Metropolitan Area are surface water (87%), river-bed water (3%), and groundwater (10%). However, these percentages for Fukuoka City are 95%, 4%, and 1%, which indicate that groundwater as a water supply source is extremely small, whereas the ratios are 66%, 1%, and 33% for the surrounding municipalities indicating fairly high ratio of groundwater. One reason for the small use of groundwater in Fukuoka City is that the alluvial aquifer here is too thin so that salt water intrusion may occur when too much groundwater is pumped up. Another reason is recent groundwater pollution problems caused by chlorinated hydrocarbons such as trichloroethylene and tetrachloroethylene and also pesticides and herbicides (Jinno *et al.*, 1986).

Furthermore, there are no major rivers in the area of Fukuoka Metropolitan Area, only several small rivers, so that the river water utilization rate is considerably high, e.g., in Fukuoka the rate is 58% in a normal year and 67% in a designed drought year (Ueda, 1986).

Since the time Fukuoka City started the water supply service in 1923, expansion projects have been carried out 18 times in order to cope with the rapid increase of water demand due to the concentration of population in urban areas, development of industries (urban infrastructure), the increase of living standard, etc. The big number of expansion projects shows the efforts which the city has taken in order to develop and efficiently utilize the scarce water resources.

Figure 2 shows the water supply and demand change with population increase for both Fukuoka Metropolitan Area and Fukuoka City. From the figure, it is seen that the increase in population of Fukuoka Metropolitan Area is larger than that of Fukuoka City, which means the population increase is more serious in surrounding municipalities being commuting towns of Fukuoka City. Also, the figure shows that mean water demand before the drought in 1978 was increasing rapidly, then it dropped drastically at the year of the drought. After the drought, the increase in daily water supply is not as big as before in spite of the large population increase. This indicates that the mean daily individual water supply has not increased since the drought. The mean daily individual water supply of about 330 liters in Fukuoka City after the drought is actually smaller than that of other large cities such as 430 liters for Tokyo Metropolis, 570 liters for Osaka City, 400 liters for Nagoya City, and 400 liters for Hiroshima City. The maximum daily water supply drops again in 1982. This is because Fukuoka City and another town carried out water supply rationing during several days that year.

Figure 3 illustrates present waterworks facilities, water sources and conveyance

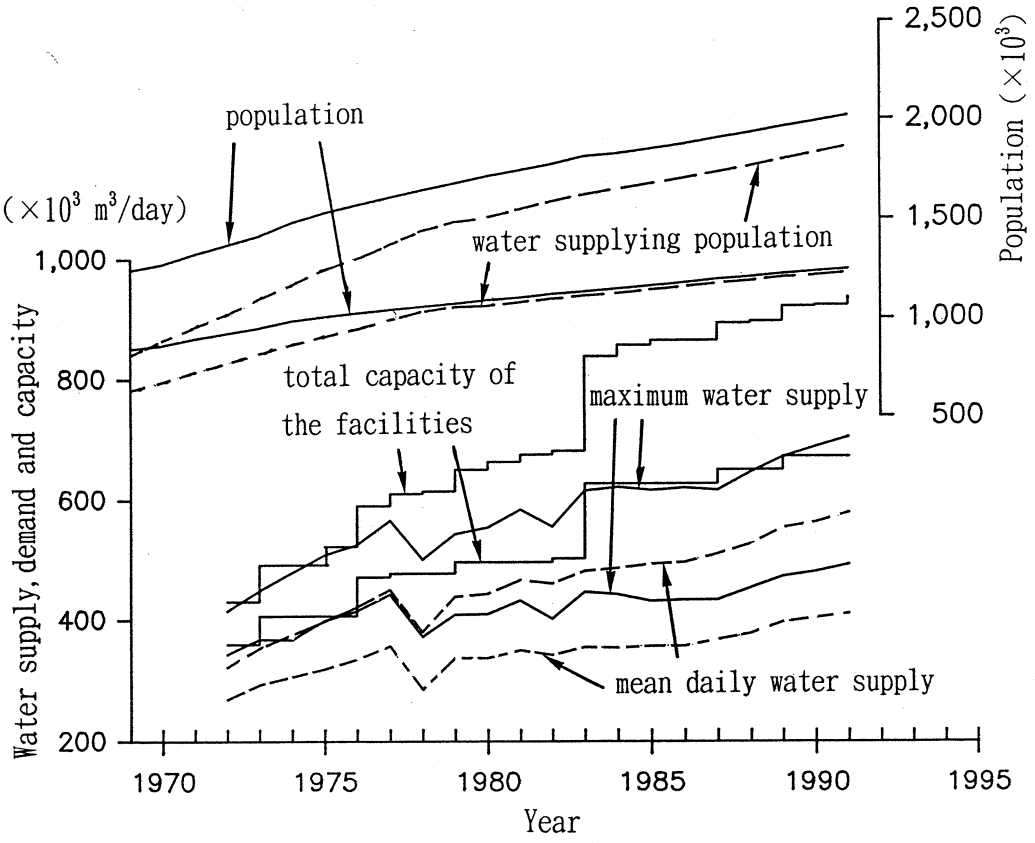

Fig. 2 Change of water supply and demand with population increase for Fukuoka Metropolitan Area and Fukuoka City.

system of Fukuoka City. Fukuoka City is withdrawing water from five small rivers that flow through the city and that are managed by the prefectural government. They are Zuibaiji, Muromi, Naka, Mikasa and Tatara Rivers. These rivers do not have sufficient and stable discharge due to small catchment areas. The city is also receiving water (purchasing water) from the Chikugo River located outside the Metropolitan Area limits. It is the biggest river in Kyushu managed by the government. The water supply capacity as of March 1992 was 673,300 m^3/day as shown in Fig. 2. There are five water purification plants and all of them are treating water by rapid-filtration. From these purification plants, water is distributed by gravity to areas less than 80 meters above sea level (Fukuoka Waterworks Bureau, 1992). These purification plants had their own supplying areas in the city and were operated independently until the drought. After the drought, a project for an integrated water supply system was started. At present, water is distributed between purification plants and optimization of water pressure is made by a water distribution control system which consists of electrically controlled valves, flow meters and, water pressure gages. Table 1 shows the outline of the dams supplying water to Fukuoka City. As seen, the general capacity and catchment of these dams are small.

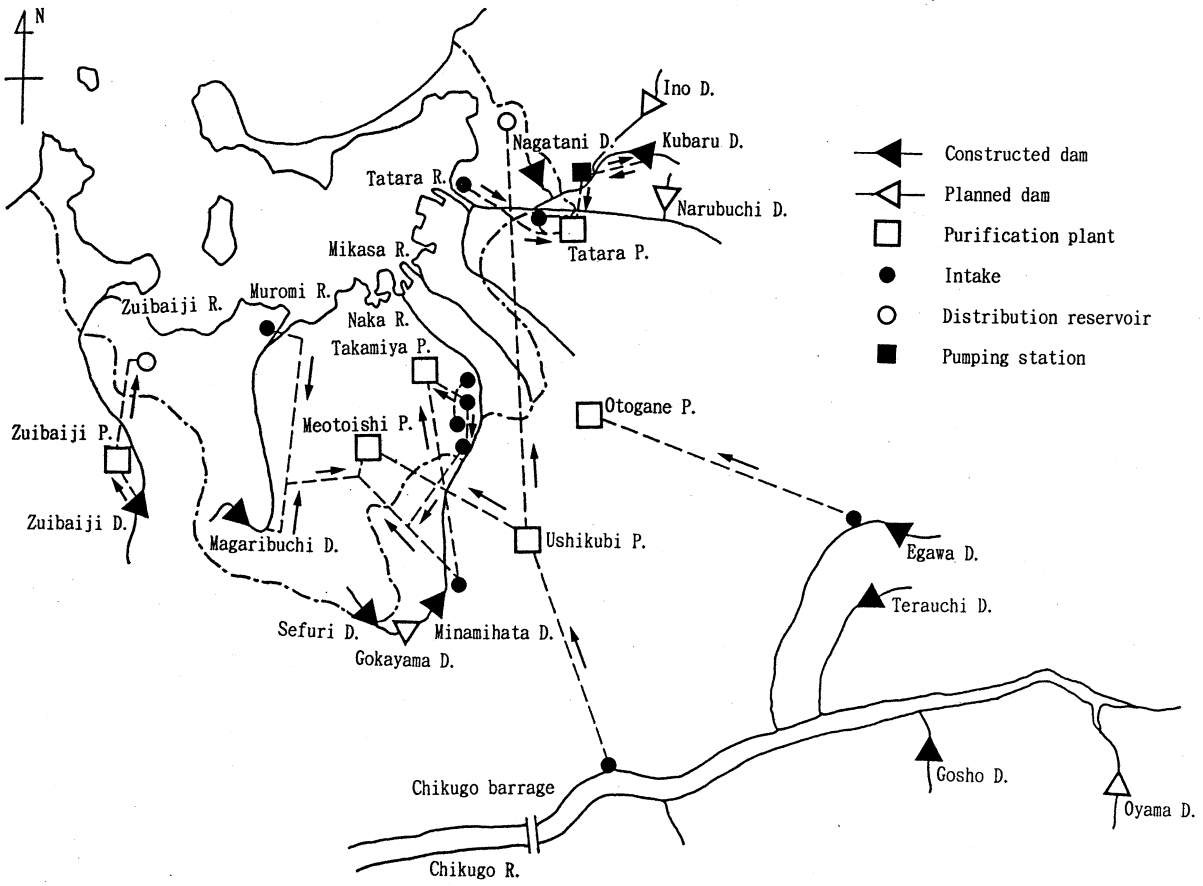

Fig. 3 Waterworks facilities, water sources and conveyance system of Fukuoka City.

Table 1 Dams supplying water to Fukuoka City.

Name of dam	Catchment area (km^2)	Capacity (thousand m^3)	Purpose *)	Jurisdiction
Magaribuchi	11.4	2,270	C	City
Minamihata	27.5	5,560	F,Ir,C,E	Prefecture
Kubaru	0.9	1,460	C	City
Egawa	30.0	24,000	Ir,C,In,E	Corp. of WRD
Sefuri	5.5	4,401	C	City
Zuibaiji	7.2	2,270	F,Ir,C	Prefecture
Nagatani	1.8	4,850	C	City
Ino	5.5	4,910	F,Ir,C	Prefecture
Narubuchi	6.8	4,160	F,Ir,C	Prefecture
Gokayama	18.9	39,700	F,Ir,C,D	Prefecture

*) F : Flood control Ir : Irrigation C : City water In : Industry
E : Electric power D : Drought measures

UNIQUE WATER RESOURCES DEVELOPMENT AND MANAGEMENT

As mentioned above, in order to meet increasing water demand in areas with scarce water resources, development projects with innovative ideas, unique for Japan, have been carried out. Also, various kinds of measures to halt the rapid increase of water demand have been introduced. These water resources development and management projects mainly implemented in Fukuoka City are described in the following.

Preservation of forested infiltration areas

Forested areas have a well-known function to store infiltrated rainfall in the ground and moderating rapid flood discharge. With deforestation, deterioration of water quality in reservoir and inflow of silt by erosion are also obvious. Therefore, the authorities have created a special fund to purchase and preserve forests that serve as infiltration areas since 1980 (Oda & Ohara, 1992).

Dam development

1. Pumping up storage dam

This type of dam stores surplus water pumped up from rivers during the season when irrigation is not necessary. The Kubaru Dam and the Nagatani Dam are examples of this. These dams' catchment areas are very small as shown in Table 1 and almost correspond to their reservoir surface areas. This type of dam is not efficient for natural rainwater collection, but works well in Fukuoka City. Figure 4 illustrates the transfer of river water to the Kubaru Dam. This project started in 1971. The construction of Nagatani Dam has just finished (1993), but is not yet in operation.

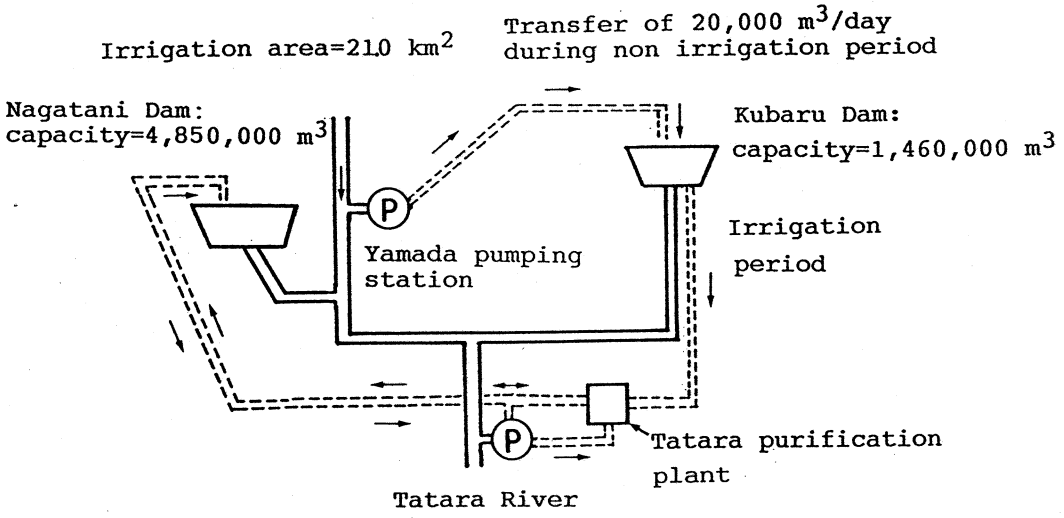

Fig. 4 Illustration of pumping up storage dams.

2. Dredging of dam beds

By this method water resources are utilized more efficiently by digging out the bottom of reservoirs to increase the usable storage capacity. An example of this is the Minamihata Dam which developed 25,000 m^3 of water per day in 1984.

3. Dam for drought control

This type of dam is designed to provide a stable supply of water during drought periods. The type of dam is planned to be constructed in the upper stream of Minamihata River as the first case in Japan. The total effective water storage capacity of this multi-purpose dam (Gokayama Dam) is 39.7 million cubic meters out of which 16 million cubic meters are to be used in case of drought, and is expected to be completed by the end of year 2000.

Improvements of water usage and existing facilities

1. Increasing efficiency of irrigation water

Generally, irrigation water is supplied by an open channel, however, there is usually great losses involved in this method. Therefore, in order to use water efficiently and to prevent losses, pipes are laid to replace open channels. As a result, excess water brought about by this system is now diverted for service water. Figure 5 illustrates the concept of the method (Jinno *et al.*, 1989). This method was implemented at two water intakes of the Naka River in 1969 and 1980. It saved totally 50,000 m^3/day.

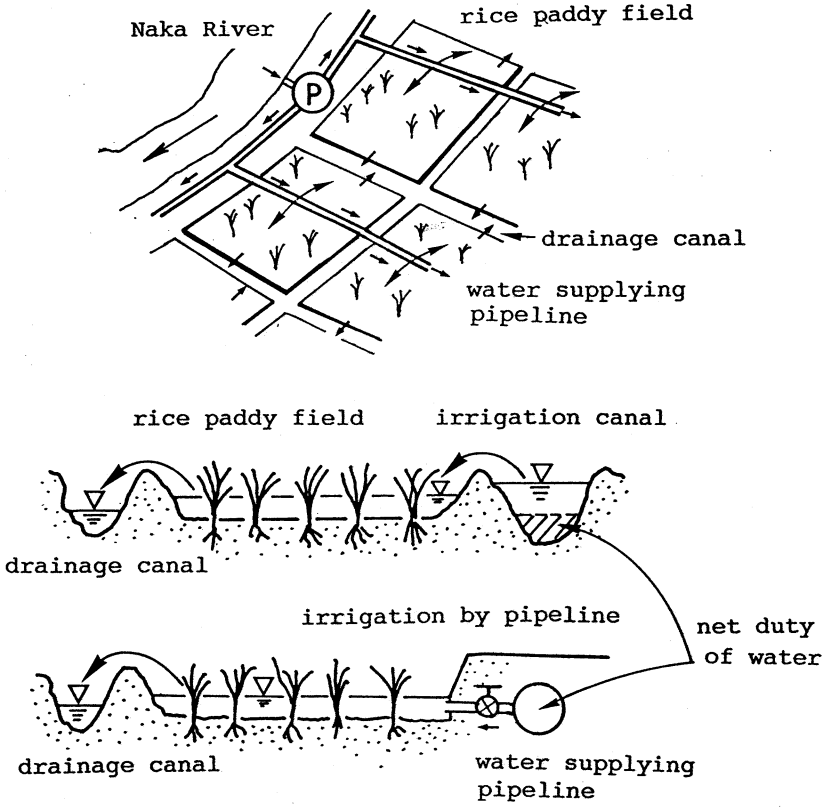

Fig. 5 Concept of irrigation water supplying by pipelines.

2. Advanced water treatment

Figure 6 shows a system that discharges treated sewage water (30,000 m^3/day) from a sewage treatment plant in the Mikasa River drainage area into the Naka River (Jinno *et al.*, 1989). The treated water is used for not only maintaining the natural river water flow (15,000 m^3/day) but also for industrial water use (15,000 m^3/day). By diverting the industrial water from the Naka River to city water, the same amount of water is taken at the upper stream for water supply to the city. This project was completed in 1985.

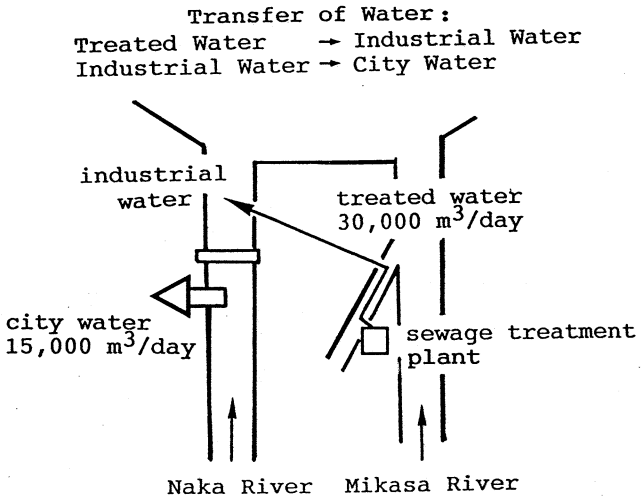

Fig. 6 Transfer of treated sewage water for industrial use.

3. Water leakage prevention

Figure 7 shows the change in water transport efficiency in Fukuoka City (Fukuoka Waterworks Bureau, 1992). Ever since the first water leakage prevention project was established in 1956, investigations have been under way. At the beginning of the project, the effective rate of water supplying was as low as 61% as shown in Fig. 7. In 1990, however, the rate reached 94%, which is considered to be very high in Japan.

The rapid change in efficiency after 1967 was due to: increase in water leakage inspections, replacement of asbestos pipes to ductile cast iron pipes, and change of metal to plastic consumer meters. The change after 1972 was a result from concentrated inspections at places where many leakage incidents occurred and from applying the sound detection method. Furthermore, a Water Leakage Prevention Section was established in 1977 to strengthen the water leakage prevention system. At the same time, water leakage inspection of service pipes, which represent most of the water leakage cases, was carried out. The setup of a Water Control Center in 1981 also contributed to increase the efficiency.

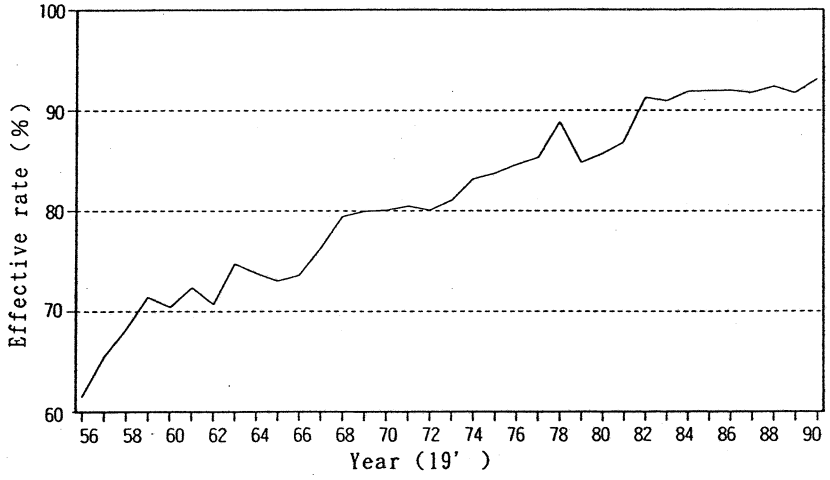

Fig. 7 Change of effective rate of water supply in Fukuoka City.

At present, in order to further improve the efficiency, water leakage prevention measures are being carried out under three basic policies (detecting water leaks at an early stage by using water leak detectors, replacing worn out pipes, and reduce water leakage by adjusting the water pressure), taking into consideration not only symptomatic treatment measures but preventive measures as well. The future target effective rate is set to 95%.

4. Water supply control

The setup of a water supply control system started when the great drought occurred in 1978. Manual valve operation during the drought caused an extremely hard work and optimal pressure control was impossible without a water supply control system. Water pressure control by this system commenced in 1981 after completion of the Water Control Center (Fukuoka Waterworks Bureau, 1992). As a part of this project, old distribution pipes were replaced and new networks were set up to make transfer of water possible among different water purification plants. Fukuoka City was the first city to introduce this system in Japan. This system includes 107 water pressure gages, 61 flow meters, and 143 electric control valves at all important points along the water distribution pipes (April, 1992). An engineer can by visual control operate electric valves by remote control in order to secure the necessary water pressure through the pipe system. By utilizing this system, it has become possible to reduce excessive high water pressure and to secure a proper and constant water pressure in order to provide better service and reduce water leakage from the pipes. The water pressure can be controlled as seen in Fig. 8 (Jinno *et al.*, 1989).

Water quality improvements

1. Utilization of treated sewage water

From the standpoint of water use efficiency, the authorities of Fukuoka City have established an "Outline of Measures for Conservation Type Use of Water in Fukuoka City" through the lessons obtained during drought in 1978. As a part of this outline, the re-use of treated sewage water has been introduced. This system recycles the non-potable highly treated

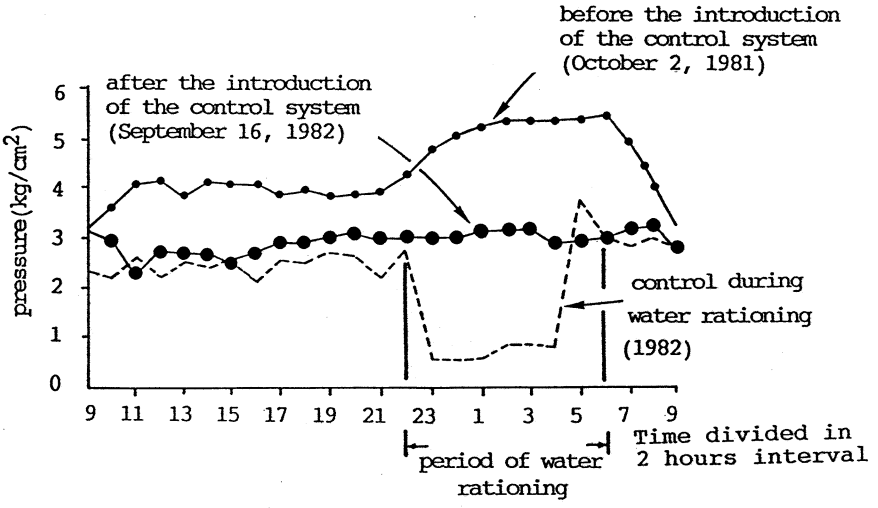

Fig. 8 Water pressure cntrolled by water supply control system.

waste water mainly for flushing toilets. This system uses the following three methods (Fukuoka Waterworks Bureau, 1992).

1) Individual circulation

This means that individual disposal facilities circulate their own treated water at each individual building such as offices, schools, and hotels. The method is applied to large-sized buildings of a total floor space above 5,000 square meters or with service pipes of 50 mm in diameter or more which are constructed after December 1978. Developers are obliged to install the system in spite of high investment and operation/maintenance costs. As of the end of 1989, 165 buildings have introduced this system.

2) District circulation

This is a method in which disposal facilities are set up jointly by owners of offices and buildings at the time when large-sized collective projects such as housing complexes and urban redevelopments are carried out. The method is implemented in two districts.

3) Regional circulation

This means that treated water are supplied on a large scale to offices and buildings in a certain area. The method was firstly introduced as a model project of the Ministry of Construction in 1979. Water treated at a sewage treatment plant is supplied to buildings downtown from 1980. The present supplying capacity is 2,000 m^3/day.

2. Desalination of sea water

At present, research and surveys for the feasibility of desalination are conducted using sea water on a large scale. On a smaller scale, however, a desalination plant has already been constructed at a small island of Fukuoka City. This plant has been in operation since September 1991. The capacity is 20 m^3/day by means of the reverse osmosis method.

Regional water transfer

Among the water resources development projects, the water withdrawn from the Chikugo River (Fig. 3), which is located outside of the Fukuoka Metropolitan Area, supplies approximately one third of the total water for Fukuoka City. The Fukuoka District Waterworks Agency, which is composed by representatives of each municipality of Fukuoka Metropolitan Area, was established in 1973 aiming at water supply to the entire metropolitan area. In 1983, regional water transfer from the Chikugo River started even though it was opposed by people living in the basin. This was because flow rates decreased for fishery and because of environmental issues. The agency was originally transferring water from the Chikugo River only, but now other rivers are also involved. At present, the agency is playing a very important role as a water supply administrating agency for the metropolitan area.

Measures for controlling water demand

1. Popularizing water saving equipment

Every municipality is promoting water saving equipment such as special taps, water saving toilets, and so on. Water saving taps have a gadget to control water flow. By using this tap, one cubic meter can be saved per month (Oda & Ohara, 1992). This equipment was introduced from 1978, and the usage rate is now 92%. Water saving toilets are units designed to use 8–10 liters of water each time for flushing, whereas a normal one uses 12–

16 liters. The total number of these units installed in Fukuoka City is more than 335,000 (1991). Other water saving equipments are also being actively promoted.

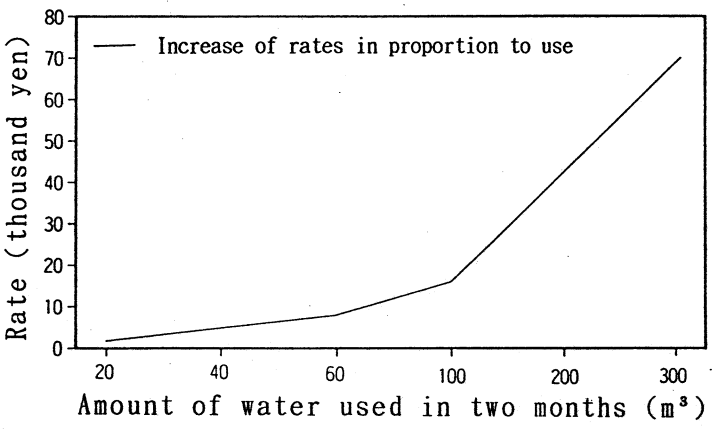

Fig. 9 Relation between amount of water used and its rates.

2. Increase of water saving awareness

The authorities have run extensive advertising campaigns to maintain and increase the water saving awareness of citizens. For instance, "Water Saving Day" on June 1, "Waterworks Week" during June 1–7, "Water Day" on August 1 and "Water Week" during August 1–7 were introduced for that purpose. Many events aiming at increasing water saving awareness are performed during these periods. Also, various kinds of leaflets, pamphlets, and videos are produced and circulated among school children and public.

3. Water cost policy

The system used means that the cost increases rapidly as the amount of water usage increases. Most of the municipalities of Fukuoka Metropolitan Area have introduced this system. The rate system implemented in Fukuoka City is shown in Fig. 9 (Fukuoka Waterworks Bureau, 1992).

4. Regulations concerning water supply rejection

Eight small municipalities surrounding Fukuoka City, for which the water supply situation is very stringent due to rapid population increase (commuting towns for Fukuoka City), have introduced regulations which enable the authorities not to supply water to newly constructed large buildings. In one of the municipalities, however, a housing developer has brought a suit against the regulations to court. The point of this lawsuit is whether the authorities have to obey the water supply responsibility as stated in the waterworks law or if they can decide their own regulations. The judicial dispute is still going on.

CONCLUSIONS

The municipalities in Fukuoka Metropolitan Area are making comprehensive efforts for supplying a stable amount of water as mentioned in this paper. Drought is caused by an imbalance in water demand and supply, which depends on rainfall and climatic situation. At present existing water resources are highly developed and water utilization is becoming more and more complex and countermeasures against droughts beyond the designed scale is becoming a great concern. Because of small excess reserves, effects of droughts may be tremendous. The establishment of water networks covering the entire Fukuoka Metropolitan Area is one of the keys for establishment of stable water supply and increasing the

robustness of the system.

Urbanization has meant population centralization, which is one of the important factors for water supply and demand imbalance. This is of importance not only in the city areas but also in surrounding towns. Future development plans have to consider the constraints brought about by the limited water resources in the area in order to make the robustness of water supply system become high.

ACKNOWLEDGEMENT

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