RETROSPECT OF WATER QUALITY CHANGE IN THE YODO RIVER DURING THE LAST 40 YEARS

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The Yodo River is the biggest river flowing into the Osaka Bay in the Seto Inland Sea, Japan, and the Osaka Metropolitan Area of more than 10 million populations is developed in its river basin. The river water is utilized as the source of various water supply in the metropolitan area and the effluent returns to the Yodo River. Therefore, the water quality of the Yodo River is very important in view of the source of the urban water supply and the source of the pollutant loading to the Osaka Bay. Japanese economy was remarkably developed during the last 40 years, that is, from 1955 to 1994, and the way of living is being changed. These changes caused very large changes to water environment. The objective of the paper is to disclose the details of the long term changes of water quality, and the relationships among the water quality, its loading, the urban dynamics, and the institutional regulations by using the statistics of population, industries and others.

Study area and its development

The study area is the lower part of the Yodo River basin, and the most industrialized and urbanized part. Its area is 1/5 of the Yodo River basin, and includes Kyoto and Osaka. Water quality measurement was initiated in 1897, but this paper concerns with the water quality from 1955, because systematic measurements of the river discharge and the water quality have been conducted since 1950's. Japanese economy in the last 40 years was roughly divided into 3 terms; the first term from 1956 to 1971 when annual growth rate of Japanese economy was higher than 9% , the second from 1972 to 1992 when the growth rate was 4%, and the last one from 1992 to 1995 when the growth rate is 0.3%. During this period, the Japanese population was increased from 89 millions to 125 millions, and the annual energy supply was also increased from 560 to 5300 (in trillion kcals).

Fig. 1 shows the increase of the population in the study area. It had the 5 millions in 1955, but increased up to more than 8 millions in 1985. And it is decreasing slowly in the last 10 years. Fig.1 also demonstrates the increase of the value of shipments of the industrial products. The oldest statistical value is 8 000 billions Yen in 1965 and it was maximum at 21 000 billions Yen in 1990, but decreased a little in 1994. Thus, the population becomes 1.6 times more and the value of the industrial shipments does 2.5 times more during the 39 years. The potable water supply is increased by 2.5 times more to support the population in this area, and the daily maximum water supply was increased from 300 to 500 (in *l*/cap. day). In the case of the industrial water, its increase is not so obvious, because the amount of the used industrial water is increased, but the use of the recycled water is remarkably increased and the freshwater supplied to industries is decreased. The new water resources is 62 m^3/s developed in the whole of the Yodo River System from 1965 to 1992.

Change of the water quality in the Yodo River

The increase of the population and the shipment of the industrial products in the area brought serious problem of the water quality in the Yodo River, and it was common in receiving waters in industrial and urbanized area in Japan. The long term changes of the annually averaged concentration and loading of BOD and NH_4-N will be examined in this section. They are measured at Hirakata located at 26 km upstream from the Osaka Bay.

The change of BOD concentration was shown in Fig. 3(a) and it was more than 4 mg/*l* and the highest during 1955 and 1969, it was between 3 mg/*l* and 5 mg/*l* from 1970 and 1987, and it decreased to less than 3 mg/*l* after 1988. The annually averaged discharge in 39 years is between 145 m^3/s and 346 m^3/s and its average is 264 m^3/s. By using the BOD concentration and discharge, the BOD loading was calculated and illustrated in the same Figure. The BOD loading was between 100 t/d and 150 t/d before 1969, and it is slowly decreasing after 1970, and becomes to 50 t/d at present, nevertheless it has large fluctuation mainly caused by discharge fluctuation.

The changes of NH_4-N concentration and loading are illustrated in Fig. 3 (b). Its long term change is a little different from that of BOD, that is, NH_4-N concentration rapidly increased up to 1 mg/*l* from 1955 to 1973, and it kept 0.5 mg/*l* to 1.0 mg/*l* from 1974 to 1987, and it is decreasing to 0.4 mg/*l* after 1988. NH_4-N loading also increased up to 20 t/d in 1972, and once decreased at 12 t/d in 1979. Then, it again increased to 23 t/d in 1985 and it is decreasing and becomes to less than 10 t/d at present.

Improvement of the water quality

The improvement of the water quality can be explained by the counter measures against the pollution of the receiving public waters. The major ones are the institutional regulation and the development of the sewage system, and they will be described bellow.

The institutional regulation was firstly made by the laws established in 1958, and they regulated the water quality of receiving public water bodies and that of effluent from the industries. The system of laws has been revised and reformulated in 1968, 1970, and 1993. According to the law system, Environmental Water Quality Standards specified the Yodo River as the Type B, that is, BOD of less than 3 mg/*l* in 1970. To attain the Environmental Water Quality Standards, Effluent Standards are applied to the discharge from the point sources, and the prefectural government established more stringent local effluent standard, e.g., 20 to 120 BOD-mg/*l* in Kyoto Prefecture from 1972. These regulations stopped the increase of the BOD concentration and loading in 1970's.

The construction of the major sewerage system in the Yodo River basin began in 1939 in Kyoto, and 1940 in Osaka, however the basin-wide rate of the sewage service ratio was under 40% by 1970. During 24 years following, the sewage system has rapidly been constructed in the whole of the river basin, and the sewage service ratio is increasing up to 80%, as illustrated in Fig. 2. Kyoto City located at upstream basin of the Yodo River especially rapidly developed the sewage system, and its service ratio was up to 98% in 1994. These development reduced the concentration and loading of BOD as illustrated in Fig. 3 (a), and increased them of NH_4-N as in Fig. 3(b). In the last 10 years, the operation of the sewage treatment plant becomes more skillful, and it reduces NH_4-N concentraion and loading.

Conclusions

The water quality of the Yodo River was the worst in 1960's, however, institutional regulations, and the development of the sewerage systems successfully decreased concentration of the water quality indices in 1990's, and it brought the reduction of the pollutant loading into the Seto Inland Sea, that is, BOD loading at Hirakata was reduced from 120 t/day in 1960's to 50 t/day in 1990's, and NH_4-N loading was also reduced from more than 15 t/day between 1966 and 1973 to 8.6 t/day in 1990's. The experiences in the Yodo River basin described above will be useful for solving the similar problems in other area. Further discussions and studies on the relationships among the water quality, urban dynamics and the institutional regulations or measures should be required to improve the water environment.

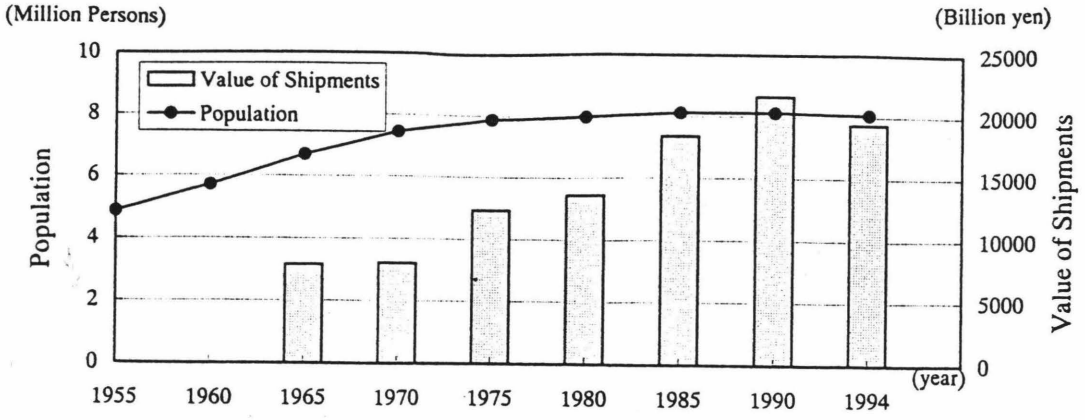

Fig. 1 The increase of the population and the industrial products in the lower Yodo River basin.

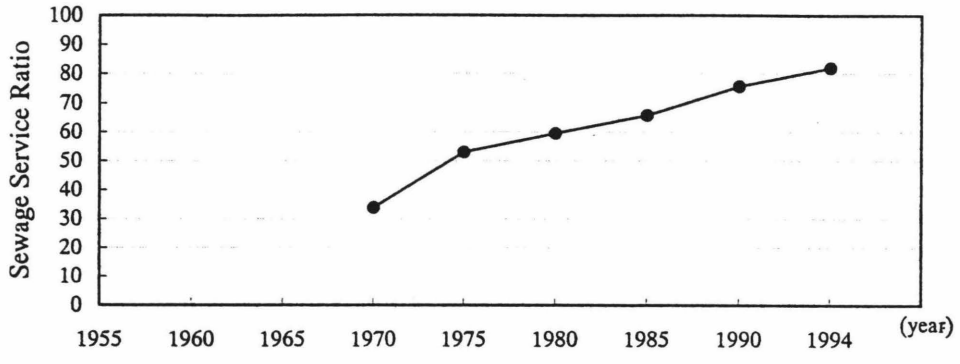

Fig. 2 The increase of the sewage service ratio.

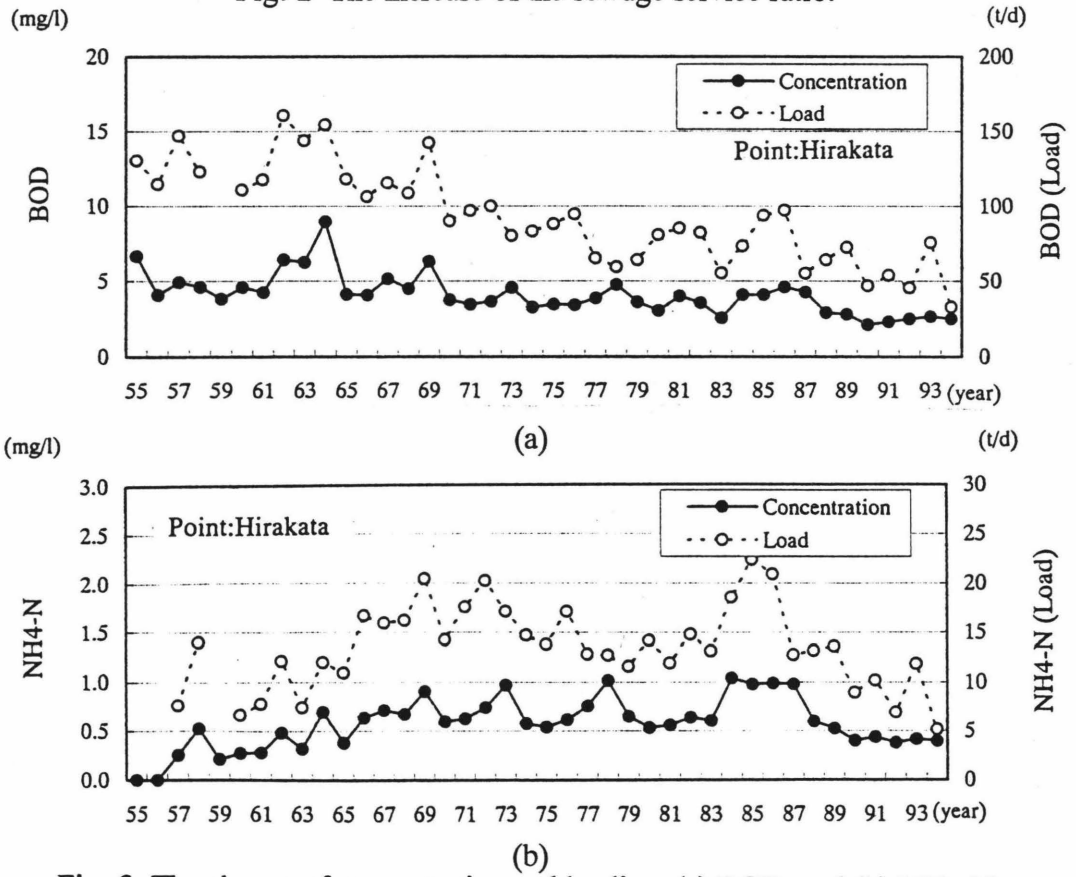

Fig. 3 The change of concentration and loading; (a) BOD, and (b) NH_4-N.