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Study on Water Quality of Surface Runoff and Groundwater Runoff on the Basis of Separation by a Numerical Filter

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In this study, we investigated the water quality of surface runoff and groundwater runoff from the basins of the Yodo River and the Asahi River based on that separated by a numerical filter. The water quality of the surface runoff is greatly different from the groundwater runoff. The tendency of concentration change in accordance with river discharges is different from each other. The water quality of groundwater runoff changes with river discharges clockwise in many cases. The differences of COD and SS originating from those of population and industrial activities in each basin are found in the lower SS concentrations of the surface runoff and the COD concentrations of the groundwater runoff. The nutrients and chlorine ion were investigated, too.

1. INTRODUCTION

In the water quality management of rivers, the differences of pollutant loads and water quality among pollutant sources are important. Pollutant loads from non-point sources occupy most loads in rainy weathers. On the other hand, loads from point sources determine loads and water quality in fine weathers together with the loads and water quality of the groundwater runoff from the forests and so on.

The components of runoff are classified into surface runoff, interflow and groundwater runoff. In this study, the components of runoff were separated into groundwater runoff and surface runoff which includes interflow. The surface runoff is major in rainy weathers and the groundwater runoff occupies most parts in fine weathers. In this study, the two components, surface runoff and groundwater runoff, of both pollutant loads and river discharges were separated by the same numerical filter and the water quality of each component is calculated from the separated components of the loads and the discharges. Based on the periods of variations, the components of the runoff were separated. The component of the shorter period was judged to be surface runoff and that of the longer period was judged to be groundwater runoff. Because data of daily means were used in this study, the periods in days are aimed. The wastewater from households is includes in a part of groundwater runoff because the variation of daily averaged wastewater is small. Therefore, the water quality of the groundwater runoff separated is similar with the water quality of the groundwater from forests in the basins of low population density and low industrial activities. On the other hand, the water quality of groundwater runoff receives the influence of urban drainage in basins of high population density and high industrial activities. The water quality of the Yodo River has been improved comparatively, however it is not so good because of high urban activities in the basin. The water quality of the Asahi River is good because the population density and industrial activities are low in the basin. Because the degree of urban activities is greatly different in the both basins, the water quality is studied by a comparative method.

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2. DATA USED AND OUTLINE OF BASINS

The basin area of the Yodo River is about 7281km^2 including the basin area of the Lake Biwa, 3848km^2. In the basin, there are many satellite cities other than two major cities of Osaka City and Kyoto City. Data used for analysis are water quality and daily discharges observed in Hirakata City from January, 1980 to December, 1980.

The basin area of the Asahi River is about 1,800 km^2. There are Asahigawa Dam and Yubara Dam in the basin and the total reservoir capacities are about 60,000,000m^3 and 100,000,000m^3, respectively. The river discharges are rather stable. The data used for analysis are water quality observed a little upstream from the upper end of the estuary and daily mean discharges observed approximately 2 km upstream from the sampling point from November,1980 to October, 1981. The daily mean pollutant loads used for the analysis were calculated from the water quality and the daily mean discharges.

3. FILTER SEPARATION AUTOREGRESSIVE METHOD(1)

In this study, the water quality of surface runoff and groundwater runoff was investigated. Each component of water quality was calculated from the components of discharges and pollutant loads obtained by means of a filter separation autoregressive method. By the way, the variations of river discharges and pollutant loads can be classified into those of the longer period and the shorter period. The river discharges used for filter separation autoregressive method are classified into those in hours and those in days. Both are different from each other in the analyzing method of time series. The former is analyzed as a stationary probability process, but the latter is analyzed as a nonstationary probability process. In other words, rain is considered as a white noise in the former, whereas the rain is considered as an exogenous input in the latter. As time series data in days were analyzed here, the method of the former was applied.

In the following, the time series of river discharges is picked up for a example and the general statement about the analysis method is given. In the analysis the discharges from dams are deducted from total river discharges to remove the influence of the artificial control of river discharges. The daily river discharges are expressed as the following with an autoregressive model before carrying out the component separation.

$$y_i = a_1 y_{i-1} + a_2 y_{i-2} + a_3 y_{i-3} + \cdots + a_p y_{i-p} + \varepsilon_{i-1} \qquad (1)$$

Here, $a_1, a_2, a_3, \cdots, a_p$: autoregressive parameter, ε_{i-1}: white noise proportional to daily precipitation.

By the way, these autoregressive parameters are considered as the weights expressing the influence which river discharge at t receives from the precedent discharges at t-1 , t -2, and so on. When the time constant for separation is decided from the order of the autoregressive model, the numerical filter for the component separation of river discharges in days is able to be formulated.

The output for each frequency is shown as following equation.

$$|W(f)|^2 = \frac{1}{\left\{1 - \left(\frac{f}{f_c}\right)^2\right\} + \delta^2 \left(\frac{f}{f_c}\right)^2} \qquad (2)$$

Here, f_c: the separation frequency that $f_c = 1/T_c$, T_c:time constant.

With the reference to the wave pass characteristic which shows the relation between amplification factors and frequencies, the decrement coefficient is selected within the range satisfying the requirement of $\delta \geq 2$. In this study 2.5 was adopted. Within the range from 2 to 3, the difference of the decrement coefficient did not affect the calculated result. The filter parameters are calculated based on the next equations using this decrement coefficient and the time constant for separation.

$$C_0 = (\delta / T_c)^2 \qquad (3)$$

$$C_1 = \delta^2 / T_c \qquad (4)$$

Then, the numerical filter for the backward operation is shown as the next equations.

$$w(\tau) = \begin{cases} \dfrac{C_0 \cdot \exp(-\frac{C_1}{2}\tau) \cdot \sinh(\sqrt{\frac{C_1^2}{4} - C_0}\tau)}{\sqrt{\frac{C_1^2}{4} - C_0}} & \tau \geq 0 \\ 0 & \tau < 0 \end{cases} \quad (5)$$

$$y^1 = \alpha \sum w(n\Delta t) \cdot y(t - n\Delta t) \quad (6)$$

The output of daily river discharges through this numerical filter, low-frequency pass filter, is the groundwater runoff, y^1. Here, α is the parameter which is determined to satisfy the requirements that total runoff, y, is always greater than groundwater runoff, y^1. Accordingly, the surface runoff, y^2, is expressed as the next equation.

$$y^2 = y - y^1 \quad (7)$$

4. WATER QUALITY OF SURFACE RUNOFF AND GROUNDWATER RUNOFF

4.1 General Characteristics

The results are shown in Fig. 1 to Fig. 14. The general characteristics are as follows. The water quality of groundwater runoff shows different tendencies from that of the surface runoff. The change in the groundwater runoff can be grasped easily because the change process is gentle. But that is difficult in the surface runoff. The tendencies of both surface runoff and groundwater runoff are different season by season. The concentrations of the groundwater runoff are low and do not change so much in comparison with the surface runoff. But they change with flow rates clockwise.

According to the results of Sato et al.(2), the water quality does not scatter so much. And the water quality of the surface runoff can be expressed by the linear function of the ratio of the surface runoff occupied to the total river discharge however the tendency of the water quality change is different season by season. The water quality of the groundwater runoff is shown that it can be arranged in relation with the flow rate of the groundwater runoff or the river water temperature.

Of these facts, we recognized from our data that the tendency of water quality change is different season by season. The population and the hydrological characteristics in each basin studied here are greatly different from that studied by Sato et al. Furthermore, the Lake Biwa and big dam reservoirs in the basins may disturb the component separation of water quality. The further consideration is needed.

4.2 Comparison with the Asahi River and the Yodo River

The water quality items that can be compared between both rivers are chemical oxygen demand (COD) and suspended solids (SS). The following characteristics are found.

Firstly, SS is considered based on Fig. 1, Fig. 2, Fig. 9 and Fig. 10. As mentioned in the previous section, water quality of groundwater runoff represents water quality in fine weather. The water quality of the groundwater runoff is lower than that of the surface runoff in both rivers. Generally the water quality of the surface runoff in the Yodo River is 2 times higher than the Asahi River . When the river discharge is little, the SS concentrations fall down to 10g/m^3 in the Yodo River and near zero in the Asahi River.

The concentrations of the groundwater runoff in the Yodo River are stable and they vary within the range of 1-8g/m^3, those in the Asahi River vary within the range of 1-20g /m^3. The bigger variations of SS in the Asahi River suggests that 2 dam reservoirs affect the SS concentrations.

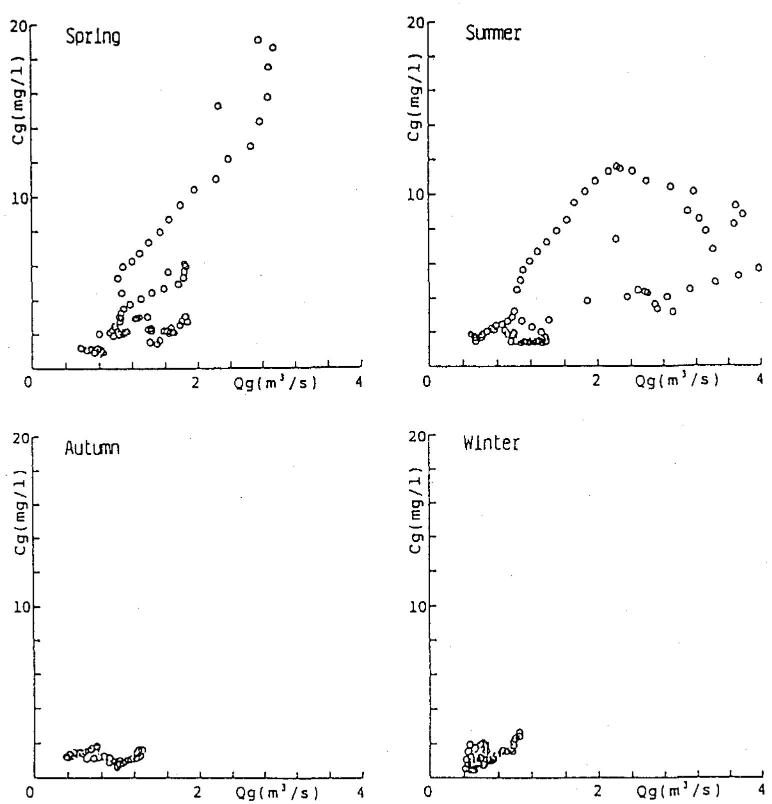

Fig. 1 SS concentration(Cg) of groundwater runoff(Qg) in the Asahi River

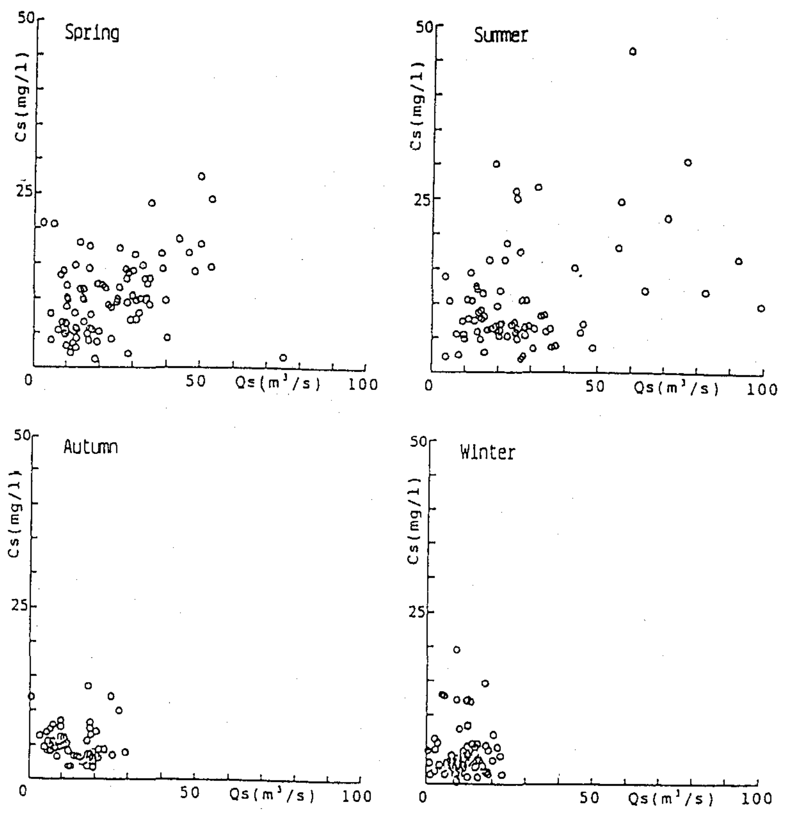

Fig. 2 SS concentration(Cs) of surface runoff(Qs) in the Asahi River

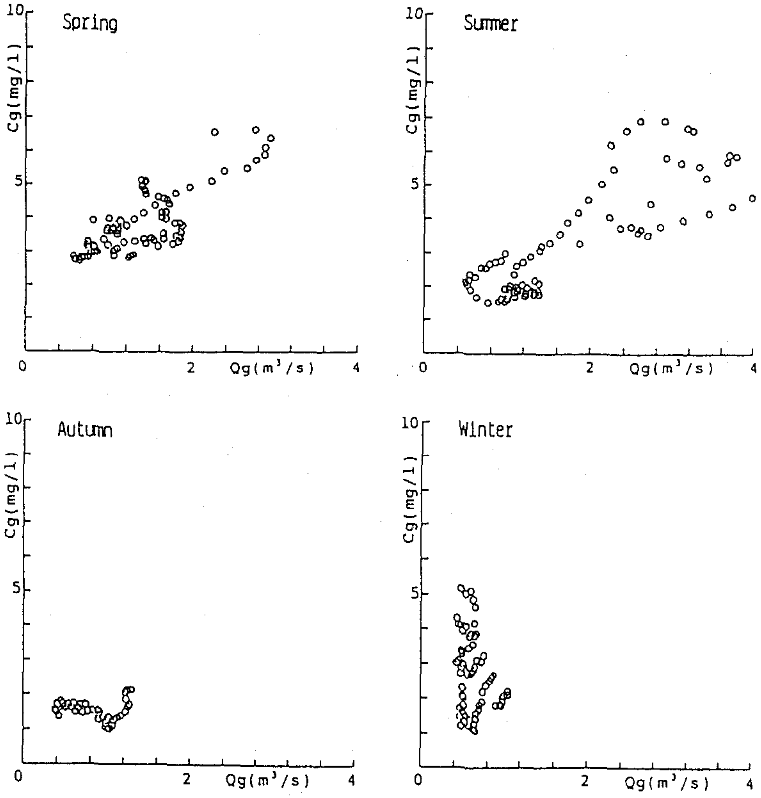

Fig. 3 COD concentration(Cg) of groundwater runoff(Qg) in the Asahi River

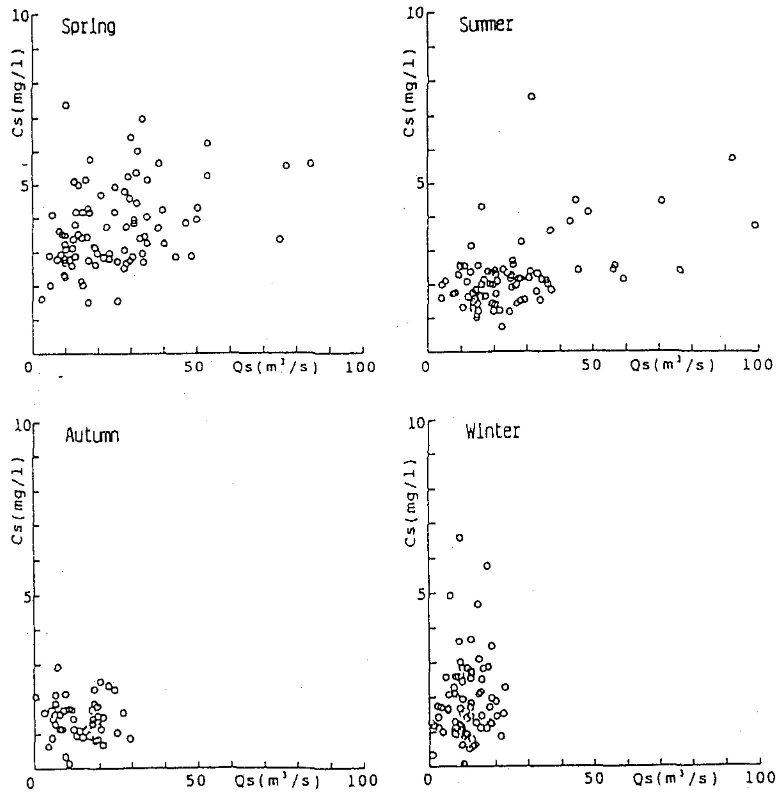

Fig. 4 COD concentration(Cs) of surface runoff(Qs) in the Asahi River

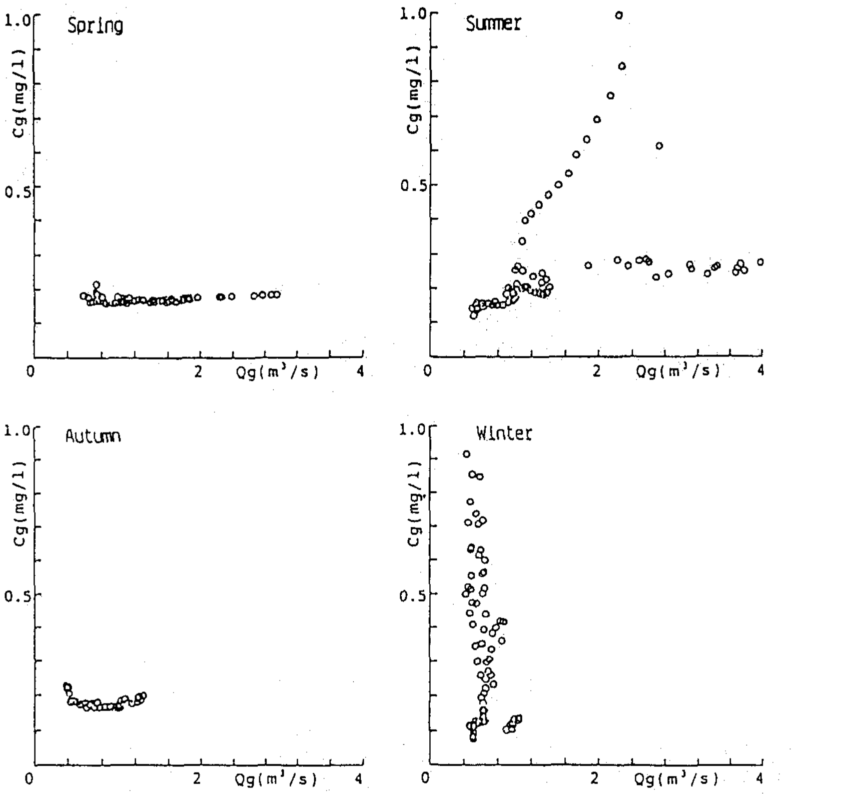

Fig. 5 TN concentration(Cg) of groundwater runoff(Qg) in the Asahi River

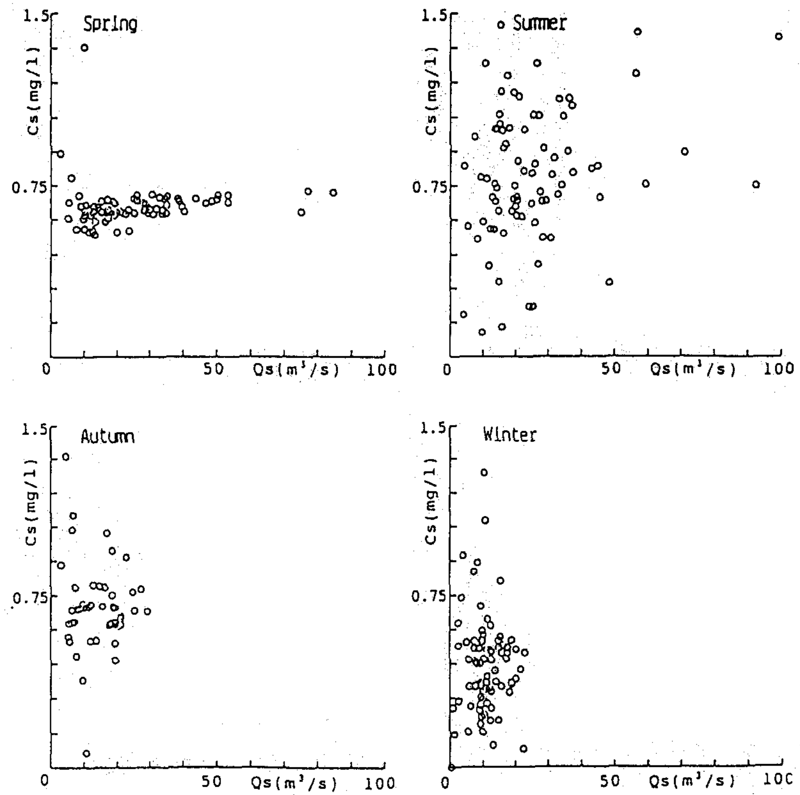

Fig. 6 TN concentration(Cs) of surface runoff(Qs) in the Asahi River

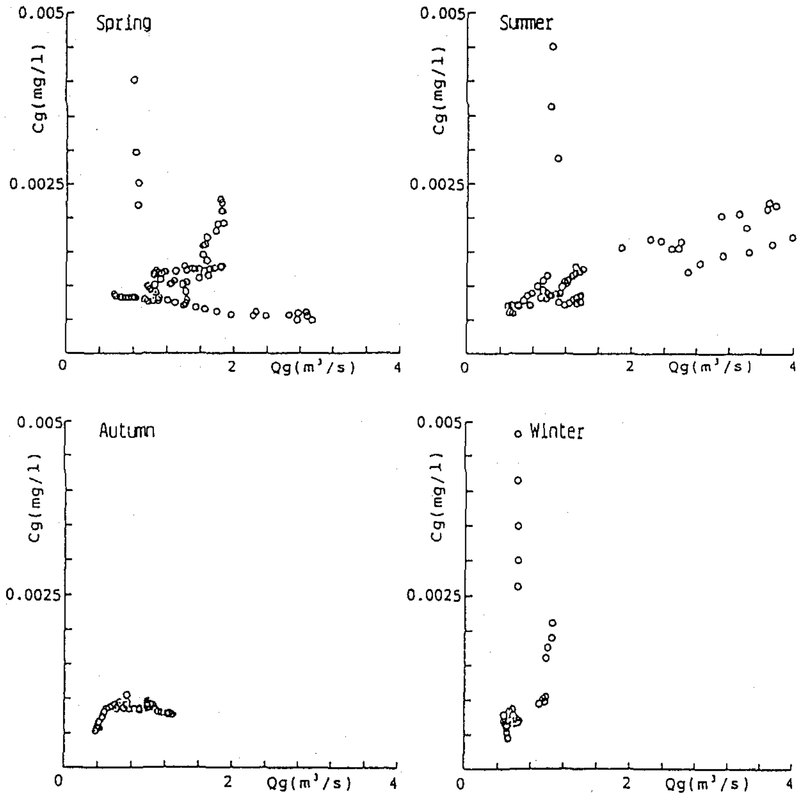

Fig. 7 TP concentration(Cg) of groundwater runoff(Qg) in the Asahi River

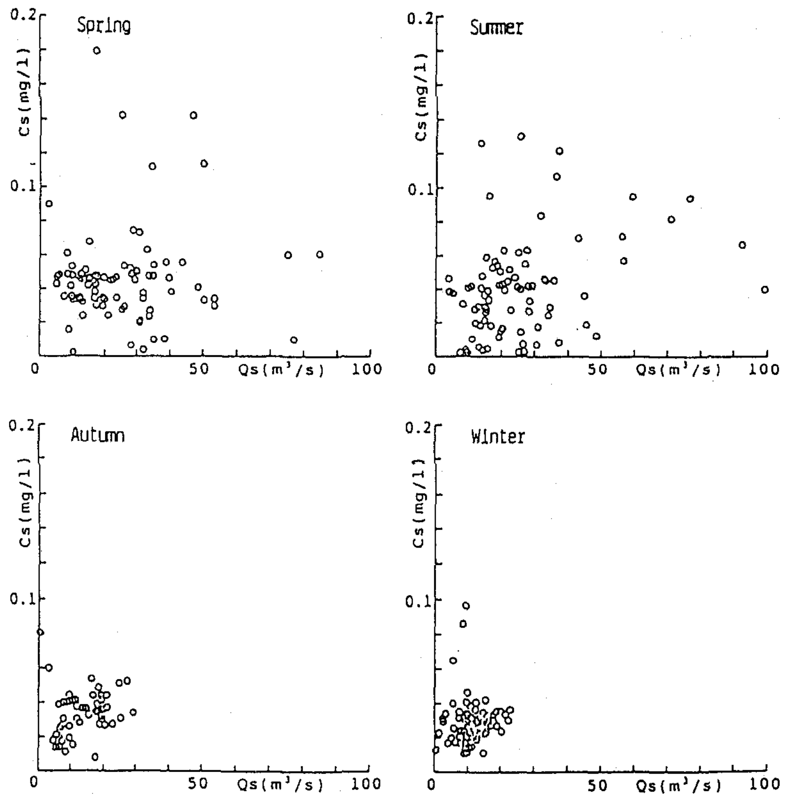

Fig. 8 TP concentration(Cs) of surface runoff(Qs) in the Asahi River

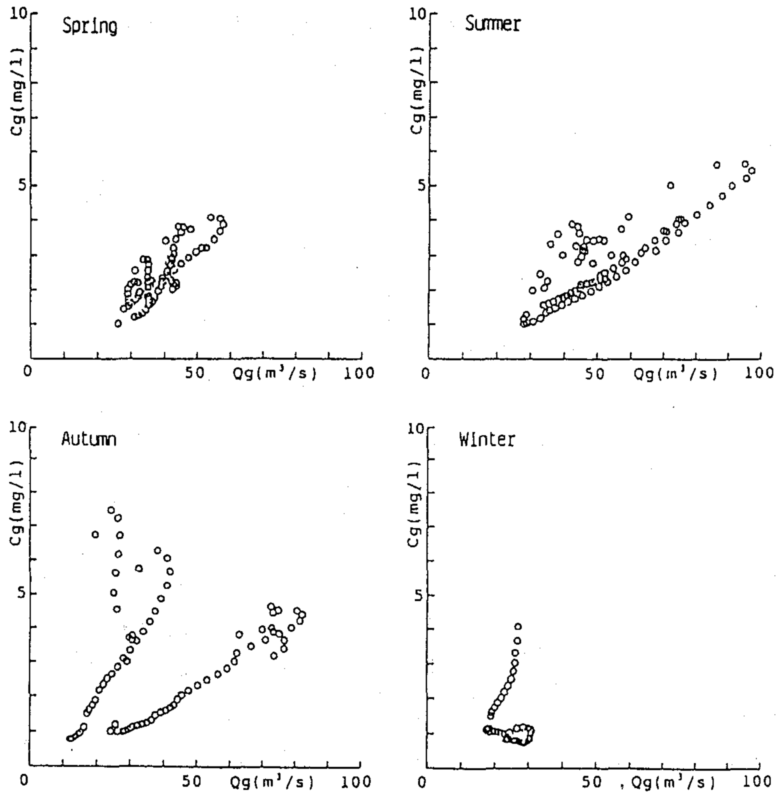

Fig. 9 SS concentration(Cg) of groundwater runoff(Qg) in the Yodo River

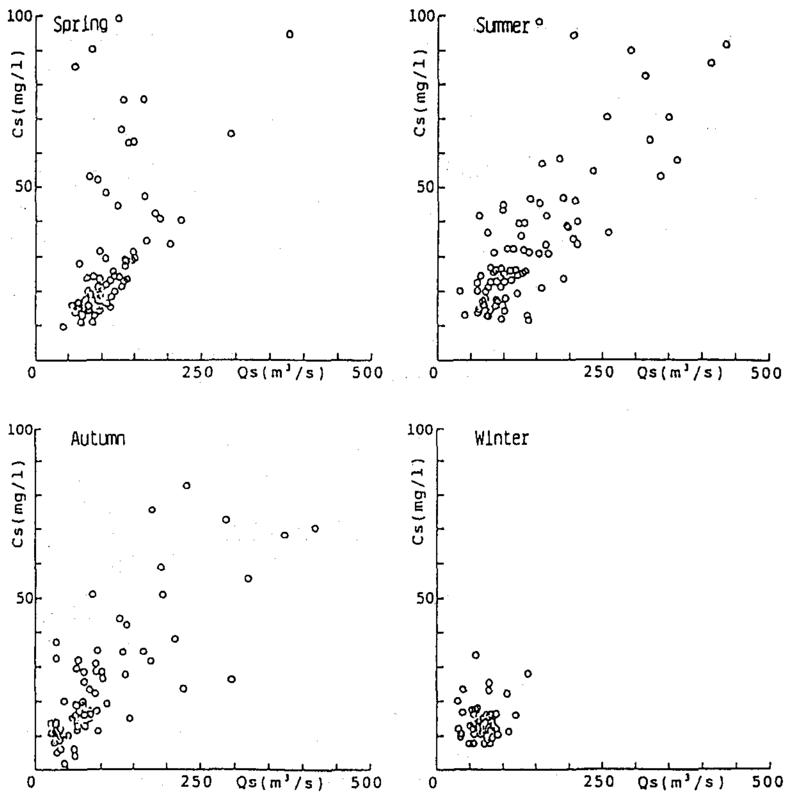

Fig. 10 SS concentration(Cs) of surface runoff(Qs) in the Yodo River

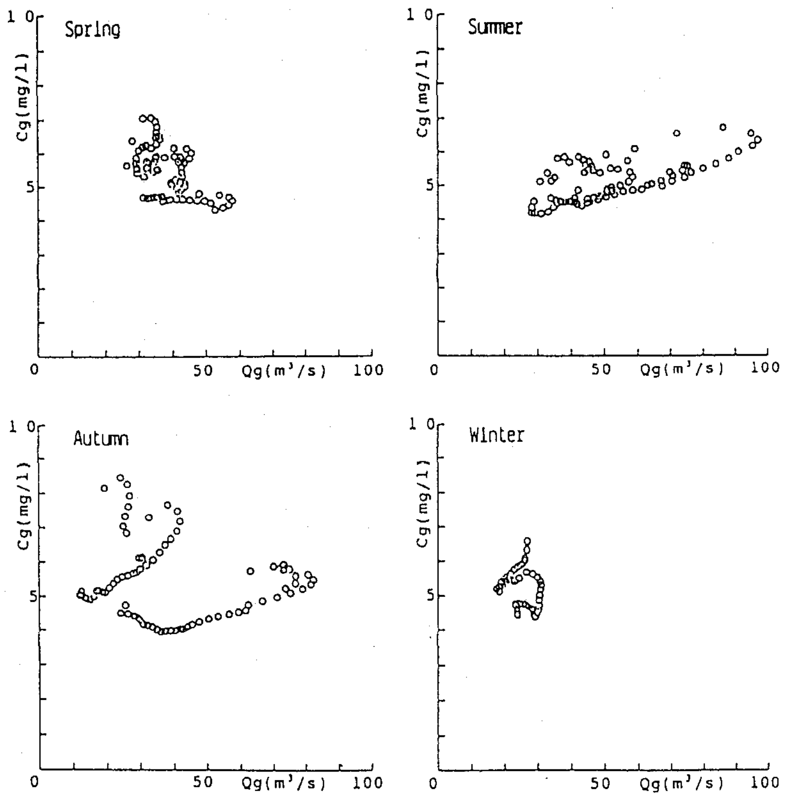

Fig. 11 COD concentration(Cg) of groundwater runoff(Qg) in the Yodo River

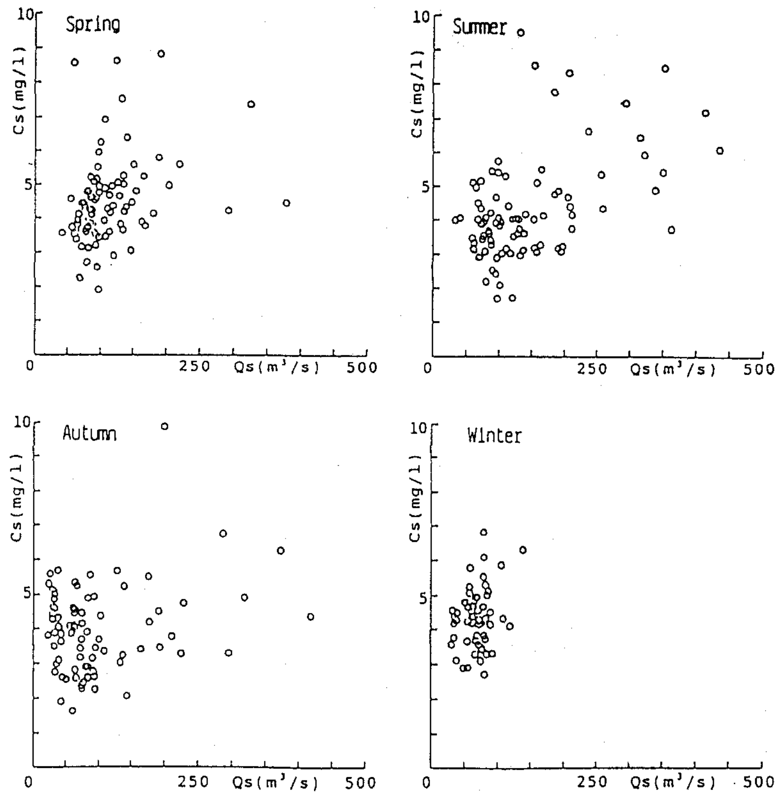

Fig. 12 COD concentration(Cs) of surface runoff(Qs) in the Yodo River

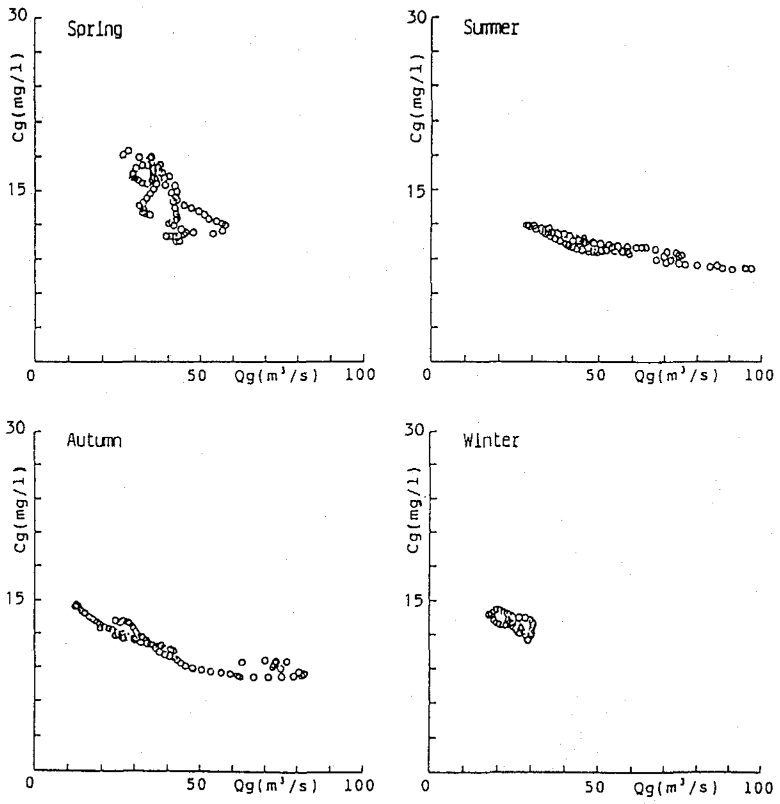

Fig. 13 Chlorine ion concentration(Cg) of groundwater runoff(Qg) in the Yodo River

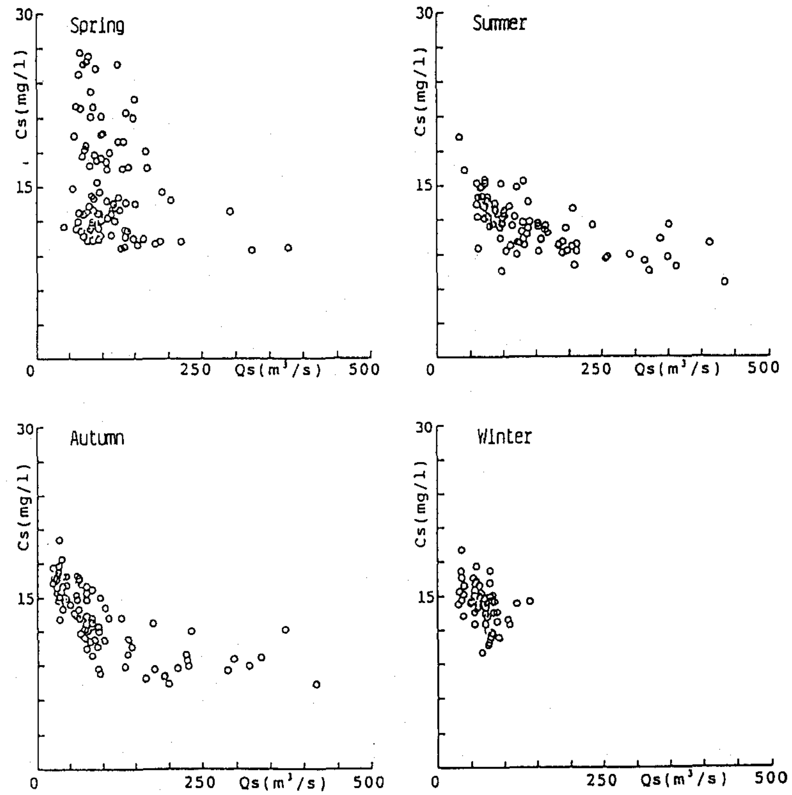

Fig. 14 Chlorine ion concentration(Cs) of surface runoff(Qs) in the Yodo River

Based on Fig. 3, Fig. 4, Fig. 11 and Fig. 12, COD is considered. In the Yodo River, the COD concentrations of the groundwater runoff are 5-10g/m^3, and those of the surface runoff are within the range of 2-10g/m^3. The concentrations of the surface runoff are rather lower than those of the groundwater runoff. In the Asahi River, the concentrations of the groundwater runoff are 1-7g/m^3 and those of the surface runoff are from near zero to 8g/m^3. Generally the concentrations of both the surface runoff and the groundwater runoff in the Asahi River are lower than those in the Yodo River. Especially, the concentrations of the surface runoff lower than 2g/m^3 ,that are scarcely found in the Yodo River, are found much in the Asahi River. It is considered that the difference of the lower concentrations shows the difference of population and industrial activities in each basin.

4.3 Concentration of Nutrients and Chlorine Ion

Total nitrate (TN) and total phosphate (TP) were observed only in the Asahi River and chlorine ion was observed only in the Yodo River. The results are shown from Fig. 5 to Fig. 8, Fig. 13 and Fig. 14.

The following characteristics are found about TN and TP. The variations of concentrations of TN and TP are similar except the spring. In the spring, the concentrations of TN are comparatively stable around 0.2g/m^3 in the groundwater runoff and around 0.7g/m^3 in the surface runoff. On the other hand, the concentrations of TP pretty change. In the summer, the concentrations of both the groundwater runoff and the surface runoff change greatly. The tendency that the concentrations of groundwater runoff change in accordance with river discharges is found. In the autumn, the concentrations of the surface runoff change to some extent, but the concentrations of the groundwater runoff do not change even if the river discharges change. In the winter, the concentrations of both the groundwater runoff and the surface runoff vary remarkably though the river discharges do not vary so much.

The concentrations of chlorine ion decrease as the river discharges increase regardless of the season and the runoff component.

5. CONCLUSIONS

In this study, we investigated the characteristics of pollutant loads from the the basins of the Yodo River and the Asahi River based on the component concentrations of the surface runoff and the groundwater runoff. The groundwater runoff and the surface runoff are each nearly equivalent to runoff in the fine weathers and the rainy weathers, and the groundwater runoff analysed here includes not only the groundwater runoff but also the wastewater from point sources.

The results obtained are as follows.

1. Water quality of the surface runoff is greatly different from the groundwater runoff. And the change process is gentle in the groundwater runoff, but it is prompt in the surface runoff.
2. The tendency of concentration changes in accordance with river discharges are different season by season in both the surface runoff and the groundwater runoff. The concentrations of the groundwater runoff change with river discharges clockwise in many cases.
3. SS of the surface runoff in the Yodo River is about 2 times higher concentration than that in the Asahi River. When the river discharges become little, the SS concentrations fall down near zero in the Asahi River and around 10g/m^3 in the Yodo River. In the groundwater runoff, the concentration of SS is stable in the Yodo River and it changes within the range of 1-8 g/m^3. It changes within the range of 1-20 g/m^3 in the Asahi River. The bigger variations of SS of the groundwater runoff in the Asahi River seem to be influenced by 2 dams in the basin.
4. In the Yodo River, the COD concentrations of the groundwater runoff are 5-10g/m^3 and those of the surface runoff are 2-10g/m^3. In the Asahi River, the COD concentrations of the groundwater runoff are 1-7g/m^3 and those of the surface runoff are 0-8g/m^3. COD in the Asahi River is generally low concentration in each runoff. In the Yodo River, the COD concentrations of the groundwater runoff are higher than those of the surface runoff in many cases.
5. The differences of water quality originating from the population and the industrial activities in each basinare found

in the differences of the lower SS concentrations of the surface runoff and the COD concentrations of the groundwater runoff.

6. The tendency that the concentrations of the chlorine ion decrease with the increase of river discharges was found in both the groundwater runoff and the surface runoff. The variations of TN and TP resemble each other and those are different season by season.

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