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Classification of Urban Rivers on the Basis of Water Pollution Indicators in River Sediment

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Urban rivers are polluted with discharge from sewage treatment plants and overflowing sewage caused by rainfall (Nix and Merry, 1990; Shiraris et al., 1987). These waste waters accelerate eutrophication of aquatic environments. Since urban river water is the public water supply source, it is an important for public health issue to determine whether or not urban rivers are polluted with fecal effluent.

In a previous paper (Miyabara et al., 1992), we reported a very sensitive detection method for urobilin by HPLC with fluorescence detection. This takes advantage of a phosphor formed from urobilin and zinc, based on the Jaffe-Schlesinger reaction (Henry, 1964 (a); (b)). Urobilin is produced in the human spleen and secreted from the duodenum through the gall bladder. Urobilin is excreted together with fecal matter and urine, and therefore directly indicates specific human fecal pollution. We estimated fecal pollution, based of the amount of urobilin present in river water and sediment (*Miyabara et al.*(a); (b)). The stability of urobilin in sediment was superior to other fecal pollution indicators. It could be that urobilin indicates fecal contamination over long time span, while NH_4-N and total coliforms indicate more recent contamination.

In this study, we attempted to classify urban rivers on the basis of the amount of urobilin, NH_4-N, total coliforms and ignition loss in sediment, and estimate the origin of water pollution.

MATERIALS AND METHODS

River sediments were collected from September 1991 to October 1992 with an Ekman-Berge dredge from rivers of metropolitan Tokyo and the Miura peninsula area (Figure 1). Samples were brought back to the laboratory and refrigerated at 4°C.

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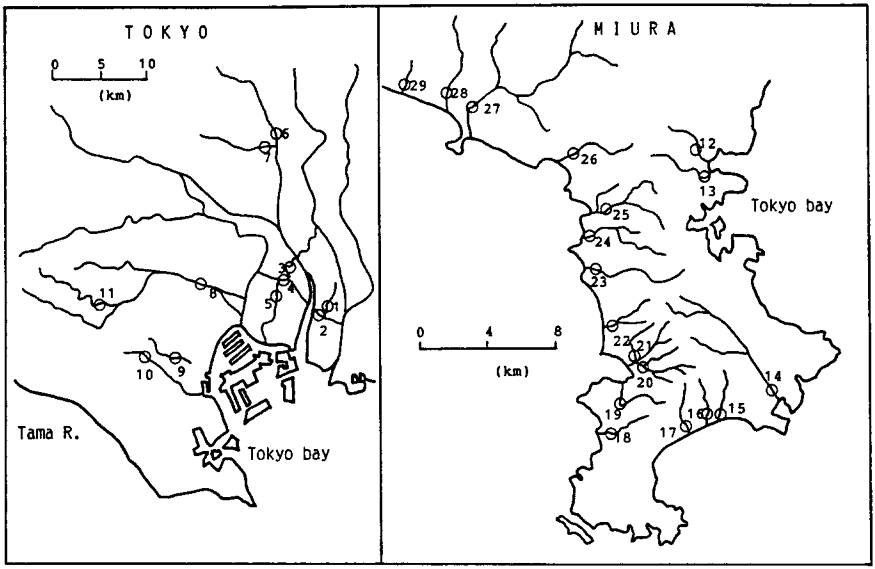

Figure 1. Sampling points of rivers.

TOKYO

1. Ichinoesakai R., Miyamoto
2. Shin R., Ukita
3. Kyunaka R., Nakahirai
4. Kitajukken R., Fukujin
5. Yokojukken R., Kurihara
6. Ayase R., Yanaginomiya
7. Kenaga R., Washimiya
8. Kanda R., Funagawara
9. Shibuya R., Shin
10. Meguro R., Nanbu
11. Zenpukuji R., Seibi

MIURA

12. Miya R., Akitsuki
13. Jiju R., Yukimi
14. Hirasaku R., Nagase
15. Nobi R., Nobi
16. Nagasawa R., Nagasawa
17. Tsukui R., Tsukui
18. Ichiban R., Wakamiya
19. Kawama R., Kawama
20. Take R., Oh
21. Matsukoe R., Maekouchi
22. Maeda R., Akiya
23. Shimoyama R., Shimoyama
24. Morito R., Morito
25. Tagoe R., Tagoe
26. Nameri R., Kaigan
27. Sakai R., Nishihama
28. Hikiji R., Kugenuma
29. Tsujido-nishikaigan 3 chome

A mixture of 100g of sediment and 1000 ml of Tris-HCl buffer was shaken at 80 rpm for 1 hr at room temperature. The supernatant was extracted with chloroform at pH 1.0 and evaporated in chloroform. The residue was then dissolved in methanol and filtered through a 0.45 μm membrane filter, whereupon the urobilin was measured by HPLC.

The HPLC conditions for measurement of urobilin were as follows.

A Shiseido CAPCELL PAK C18 (250 X 4.6 mm I.D., 5 µm) column packed with ODS-Hypersil was used. The flow-rate, injection volume, excitation and emission wavelengths for fluorescence detection, and column temperature were 1.0 ml/min, 10 µl, 485 nm and 513 nm, and 20°C, respectively. The eluent consisted of 0.1% zinc acetate, 75 mM boric acid, 15 mM sodium chloride, and 75% methanol, and was adjusted to pH 6.0 with hydrochloric acid. Urobilin used as the standard was purchased from Porphyrin Products Inc. (Logan, UT, USA).

The number of total coliform bacteria was counted according to the agar dilution method with desoxycholate agar medium. The bacteria were extracted from sediment as follows: 10 ml of isotonic saline was added to 1 g of wet sediment and the slurry mixed on a vortex for 1 min. The sample was diluted with sterilized water from 1/10 to $1/10^5$, then each 1 ml of sample was poured into a Petri dish with desoxycholate agar medium. The number of bacterial colonies on the desoxycholate agar plate was counted after 48 hours incubation at 37°C.

The amount of ignition loss (IL) and ammonia nitrogen were measured by the Standard Methods of Analysis for Hygienic Chemists (Pharmaceutical Society of Japan, 1990).

The classification of urban rivers was made by a cluster analysis according to Euclidean distance, on the basis of the standardized value of water pollution indicators in river sediment (Tada et al., 1983).

RESULTS AND DISCUSSION

It is well known that not only urobilin but also ammonia nitrogen, bacteria and other organic compounds are adsorbed by river bottom sediment (*Miyabara et al.*(b); Tada et al., 1983; Nix and Merry, 1990; Shiraris et al., 1987). The amounts of urobilin, ammonia nitrogen and total coliform bacteria reflect fecal pollution, while organic pollution of the river affects ignition loss. In addition, the amount of ammonia nitrogen increased as a result of decomposition of organo-nitrogen compounds in sediment and that released from factories. These amounts reflect the source of water pollution. Consequently, classification of urban rivers was made by a cluster analysis according to Euclidean distance, on the basis of standardized value of water pollution indicators in river sediment.

Table 1 shows the amount of urobilin and other indicators present in river bottom sediment from rivers in Tokyo and Miura peninsula. The amount of urobilin and total coliform bacteria in the sediment differed about five orders of magnitude; therefore, the data were converted into logarithm form. The standardized value was obtained by dividing the individual values by the logarithmic average. The histogram of these indicators is shown in Figure 2 in logarithmic form, indicating that these indicators follow a normal distribution curve.

The dendrogram was made by cluster analysis on the basis of logarithmic values of these indicators, and is shown in Figure 3. These 29 rivers were divided into two groups, as A and B. Further, this A and B group included two and three sub-groups, respectively.

Table 1. Distribution of water pollution indicators in river sediment.

		River	Sampling point	Urobilin ng/kg	NH_4-N mg/kg	Total coliform n/g	IL %
Tokyo	1	Ichinoesakai	Miyamoto	800	15.2	N.D.	8.63
	2	Shin	Ukita	2340	105	200	15.1
	3	Kyunaka	Nakahirai	43200	328	N.D.	26.2
	4	Kitajukken	Fukujin	531	28.0	2000	8.63
	5	Yokojukken	Kurihara	1780	27.7	200	11.4
	6	Ayase	Yanaginomiya	639	41.9	90	13.5
	7	Kenaga	Washimiya	1850	7.58	120	6.55
	8	Kanda	Funagawara	16300	7.19	80	5.91
	9	Shibuya	Shin	78300	3.24	10	0.69
	10	Meguro	Nanbu	6890	4.99	40	1.65
	11	Zenpukuji	Seibi	6550	4.39	50	1.24
		Average (Tokyo)		14500	52.1	253*	9.05
		S.D.		24600	96.1	583*	7.47
Miura peninsula	12	Miya	Akitsuki	193.0	25.0	600	11.6
	13	Jiju	Yukimi	60.5	59.9	500	15.0
	14	Hirasaku	Nagase	1270	28.7	700	14.7
	15	Nobi	Nobi	N.D.	0.06	1200	0.43
	16	Nagasawa	Nagasawa	2.5	0.68	80	0.51
	17	Tsukui	Tsukui	N.D.	0.25	800	5.82
	18	Ichiban	Wakamiya	N.D.	0.25	300	10.2
	19	Kawama	Kawama	12.0	2.21	1600	8.67
	20	Take	Oh	10.8	1.85	N.D.	1.78
	21	Matsukoe	Maekouchi	210.0	0.32	40	1.26
	22	Maeda	Akiya	2.1	1.09	N.D.	0.57
	23	Shimoyama	Shimoyama	1.7	0.22	4500	4.23
	24	Morito	Morito	17.9	0.18	500	3.33
	25	Tagoe	Tagoe	2.5	4.75	400	1.30
	26	Nameri	Kaigan	3.9	1.90	700	2.23
	27	Sakai	Nishihama	1070	14.7	28500	2.20
	28	Hikiji	Kugenuma	3.5	5.14	600	2.01
	29	Tsujido-nishikaigan 3chome		12.5	1.94	300	2.01
		Average (Miura)		160*	8.29	2300	4.88
		S.D.		375*	15.5	6620	4.94

N.D.: Not detected.
*: The average was calculated as N.D. = 0.2 and 1, which were the detection limit of urobilin and total coliform in sediment, respectively.

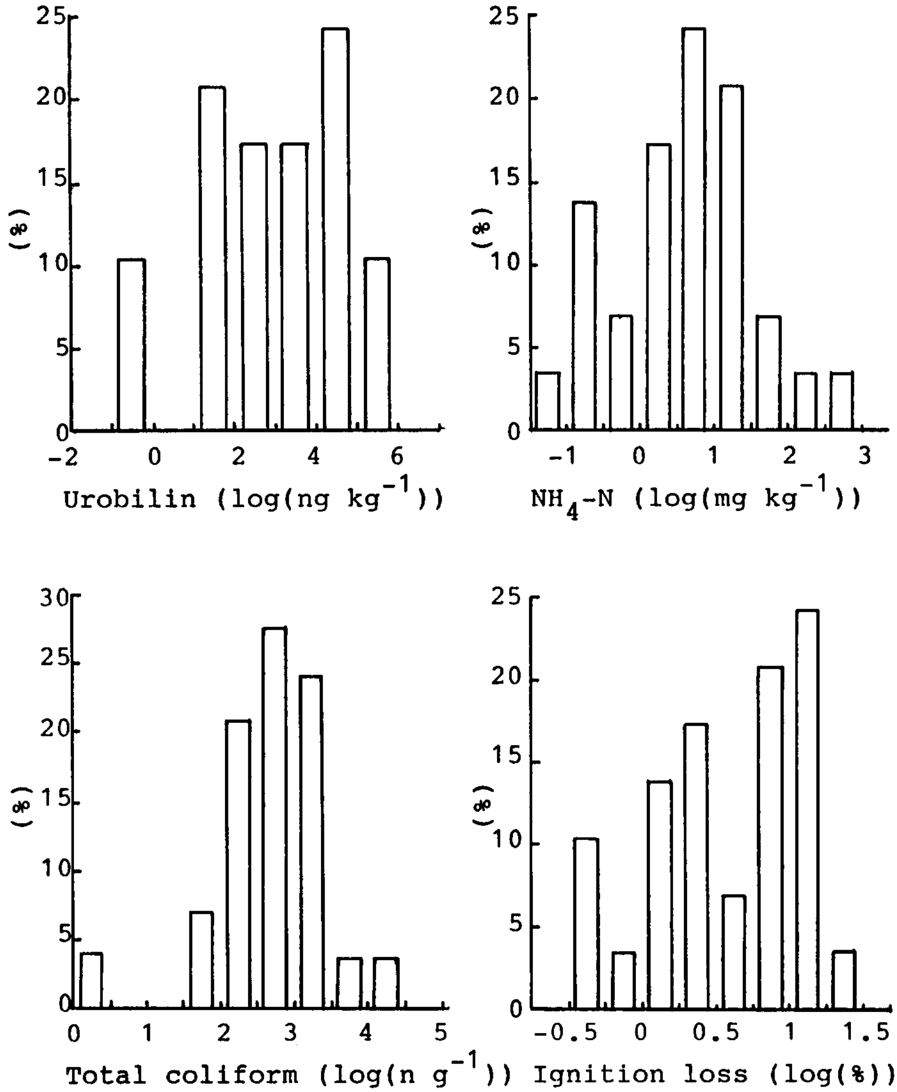

Figure 2. Histograms of the amount of urobilin, NH_4-N, total coliform bacteria and ignition loss in sediment.

In order to distinguish between them, the standardized values of the indicator amount are shown in Figure 4 and 5. For values larger than 1.0, the river is more polluted than the average of these rivers. The values of fecal pollution indicators in the A groups were larger than those of the B groups. This reflects the amount of domestic discharge, because the rivers in the A groups flow through the densely populated urban area.

The amount of ignition loss and ammonia nitrogen were greater than the value expected based on the other indicators for the A1 sub-group. Because these rivers flow through an industrial area,

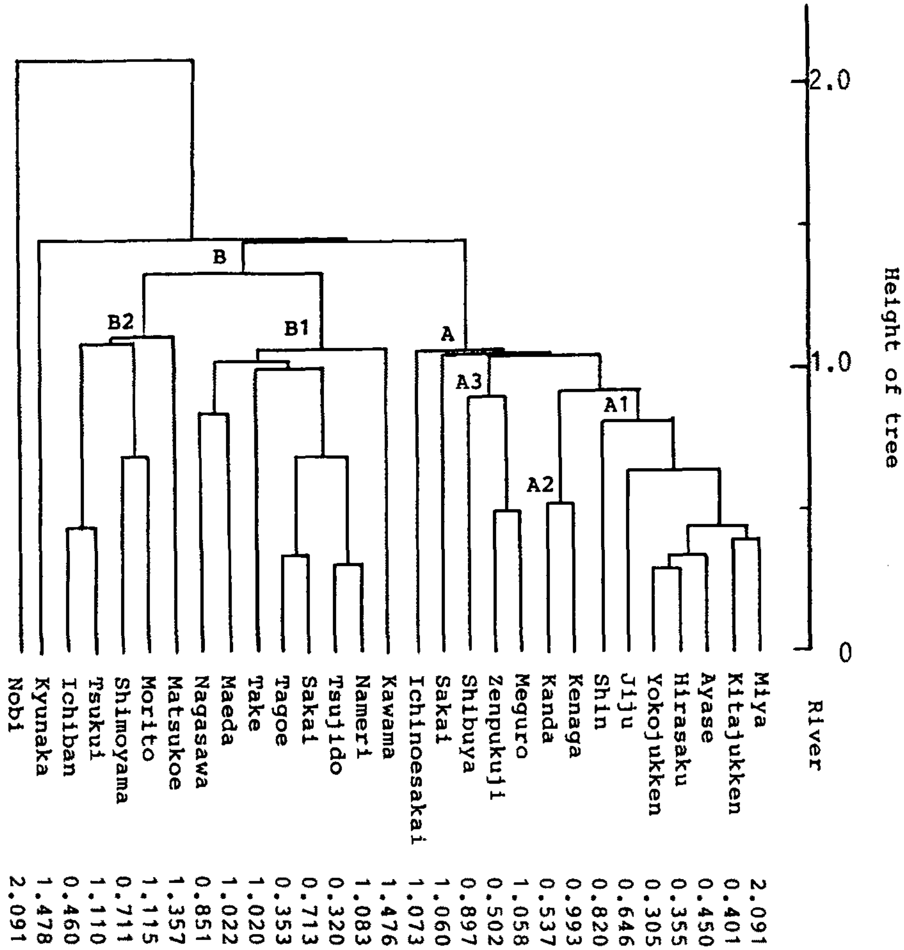

Figure 3. Cluster analysis of urban rivers based on the Euclidean n-dimensional distance method.

it reflects organic pollution from factories. The standardized value of every indicator in A2 was greater than 1.0, suggesting that these rivers are heavily polluted with fecal matter. Furthermore, only urobilin showed a large value in A3, indicating that these rivers are polluted primarily with feces.

On the other hand, the rivers in the B1 group were relative clean rivers, because the values of all indicators are lower than 1.0. In contrast, only ammonia nitrogen was small in the B2 sub-group, indicating that these rivers were especially clean.

The classification of urban rivers indicated that rivers in Tokyo were more heavily polluted with feces and discharges from factories than those in the Miura peninsula.

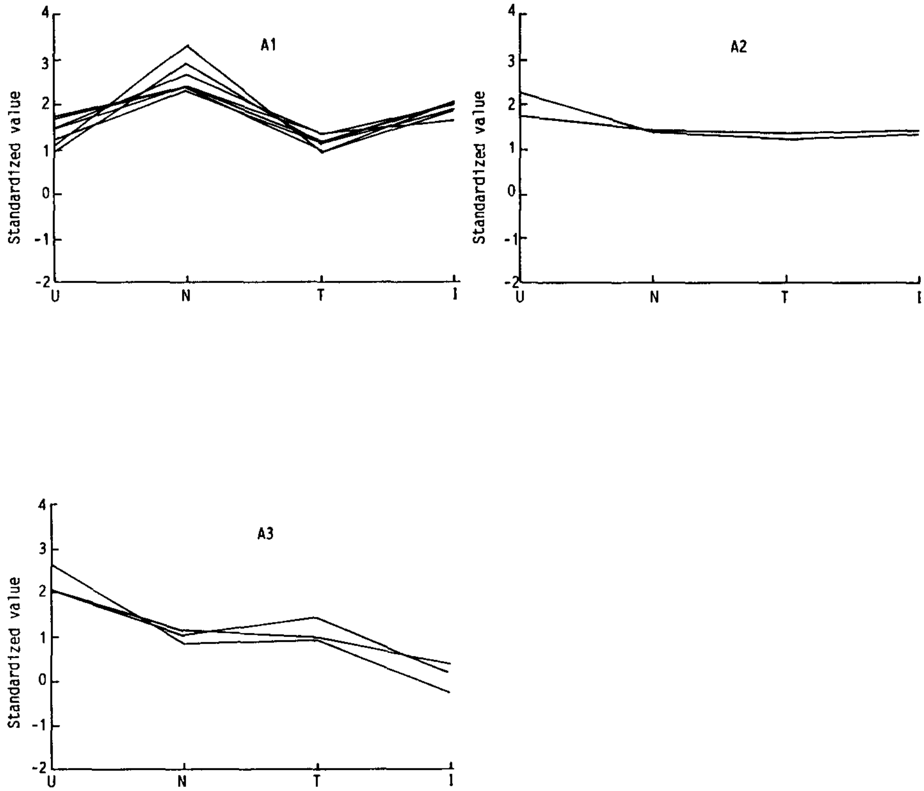

Figure 4. Water pollution patterns of A type by XY-plotter.
U: Urobilin, N: Ammonia Nitrogen, T: Total coliform,
I: Ignition loss.

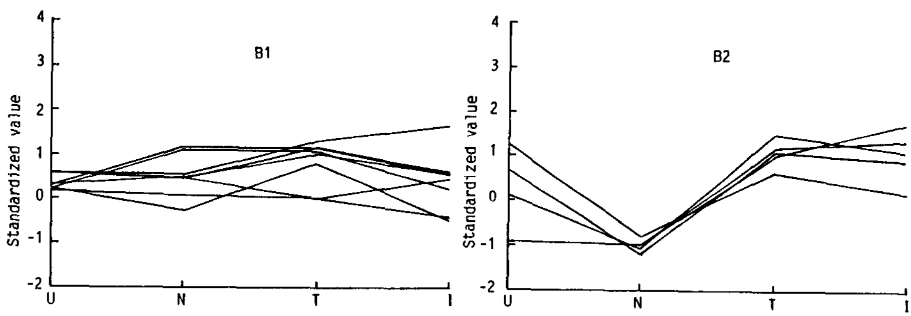

Figure 5. Water pollution patterns of B type by XY-plotter.
U: Urobilin, N: Ammonia Nitrogen, T: Total coliform,
I: Ignition loss.

Because of the population and factories concentrated in Tokyo, a large amount of discharge flows into urban rivers. These agreed with the analytical data of rivers in previous papers. Furthermore, the amount of urobilin reflected the overflow of the sewage, when the volume of water in sewage increased due to rain.

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