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Distributions of biogeochemical parameters in the pool and interstitial waters in sand bar system of the Kizu River

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ABSTRACT: Distributions of biogeochemical parameters in temporary pools (TAMARI), riparian side arm of river (WANDO) and interstitial waters were investigated in the sand bars along the lower reaches of the Kizu River. Dissolved inorganic nitrogen (DIN) and phosphate (DIP) concentrations in TAMARI and WANDO waters varied greatly compared with those in river waters. Low concentrations of DIN and DIP were often observed simultaneously in TAMARI waters. The DIN concentrations of most interstitial waters were similar or high in comparison to those of river waters. Low concentrations of DIN were observed in some interstitial waters. DIP concentrations in interstitial water of dried-up channel were low compared with those in side channel. Low concentrations of DIN and DIP were often observed separately in interstitial waters. Concentrations of biogeochemical constituents clearly varied greatly in the waters of sand bar systems, and the relationships between each biogeochemical constituents were different between surface water (TAMARI and WANDO) and subsurface (interstitial) waters of the Kizu River.

Key Words: sand bar, interstitial water, temporal pool, biogeochemical parameter, Kizu River;

Introduction

Sand bars in riverbeds have temporary pools (so-called "TAMARI") and side arms of the river ("WANDO"). The surface water in TAMARI is connected with the channel during high water levels, whereas they tend to dry up during low water levels. The saturated interstitial zone containing channel water is called a hyporheic zone. Such zones are considered to be important in river system, because the hyporheic zone provides habitats for numerous aquatic organisms (Coleman and Hynes, 1970; Hynes, 1974) and/or has high biogeochemical activities (Dahm *et al.*, 1998; Storey *et al.*, 1999). It is considered that the waters of

TAMARI and WANDO were connected with the interstitial water under the sand bar.

In this study, distributions of biogeochemical parameters in waters of sand bar system, that is TAMARI, WANDO and interstitial waters, were investigated. The biogeochemical characteristics in the waters of the sand bar ecosystem were discussed.

Materials and Methods

The Kizu River meets with the Uji and Katsura Rivers to form the Yodo River (Fig. 1). The Kizu is 102 km long and has a catchment area of 1,690 km^2. The study site is located on two sand bars 10 to 12 km upstream from the junction with the Yodo River. The length and width of both bars were about 1,000 m and 300 m, respectively. Most of the bars had bare areas consisting of sand and gravel, although vegetation patches of willow trees and vine reeds were found around the main channel. Numerous TAMARI were situated in the bars, and a WANDO was situated along the margin of the main channel in the upper bars. The water from a side channel crossed the upper bar.

Water sampling in TAMARI and WANDO was carried out biweekly and at shorter intervals after floods

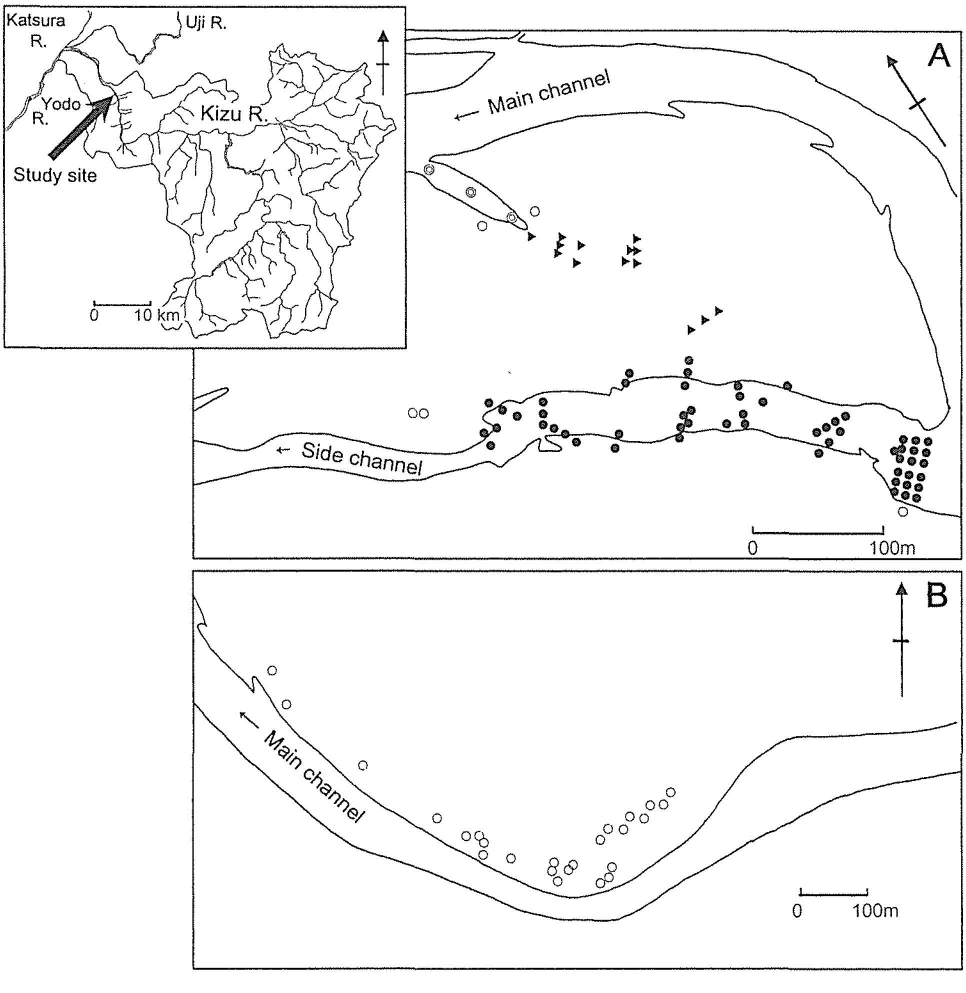

Fig. 1. Map of sampling stations at well points for interstitial waters in side channel (●) and dried-up channel (▲), TAMARI (○) and WANDO (◎) on the upper bar (A) and the lower bar (B).

between July and October 2001. All of the TAMARI existing on sampling day was investigated (Fig. 1). The WANDO waters were collected at three different stations (Fig. 1A). Samples in the interstitial waters were taken monthly between June and October 1999 and at August 2000. The interstitial waters were sampled at well points located along the side channel (S) and dried-up channel (D) (Fig. 1A). The wells along the side channel were also found in bare areas within a few meters from the side channel. The wells along dried-up channels were located on bare or vegetation areas. At each well point, Teflon or silicon tubes, whose intake was covered with acrylic fiber filter, were inserted into sandbeds to a depth of 40 or 80 cm below the water level. The water samples were gently withdrawn using a syringe. River waters were collected from the main and side channel every investigation day. For the determination of major ionic elements and silicate, the water samples were filtered through a paper filter (Toyo No. 5C) and stored in a refrigerator. Water samples for chemical analyses of nutrients were filtered through a glass-fiber filter (Whatman GF/C) and stored at -30°C. The concentrations of major ionic elements and nitrate were analyzed by an ion chromatographic analyzer (Dionex DX-120). The ammonium concentration was determined by the method of Sagi (1966), nitrite after Bendschneider and Robinson (1952), phosphate after Murphy and Riley (1962) and silicate by the method of Mullin and Riley (1955).

Results and Discussion

The concentrations of major ions (Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-}) in the river's, interstitial (S), interstitial (D), TAMARI and WANDO waters were shown Table 1. Their concentrations in each water system varied little throughout the observation period. Their concentrations between the river and interstitial (S) waters were similar, suggesting that the interstitial (S) waters originated from river water. Chloride ion is often used as a conservative component in chemical studies in rivers (e.g., Triska *et al.*, 1993). The average chloride ion concentrations in the interstitial (D) and TAMARI waters were low compared with those of

Table 1. Major ion concentrations in river, interstitial, TAMARI and WANDO waters.

			RIVER	INTERSTITIAL		TAMARI	WANDO
				S*	D*		
Na^+	(mg l^{-1})	RANGE	7.9 – 16.1	7.7 – 15.3	4.6 – 10.8	5.9 – 14.4	7.9 – 11.4
		AVERAGE ± SD	10.9 ± 2.5	10.8 ± 2.3	7.7 ± 1.1	8.8 ± 1.9	8.8 ± 1.0
		CV (%)	23	21	14	22	11
K^+	(mg l^{-1})	RANGE	2.6 – 4.2	2.9 – 5.2	0.7 – 3.8	2.0 – 6.1	2.4 – 3.4
		AVERAGE ± SD	3.4 ± 0.5	3.7 ± 0.4	2.5 ± 0.4	3.3 ± 0.6	2.7 ± 0.3
		CV (%)	13	12	16	19	11
Mg^{2+}	(mg l^{-1})	RANGE	1.8 – 2.7	1.5 – 4.8	1.2 – 4.3	1.1 – 6.2	1.9 – 2.5
		AVERAGE ± SD	2.2 ± 0.3	2.3 ± 0.4	2.1 ± 0.5	2.0 ± 0.7	2.1 ± 0.2
		CV (%)	13	16	22	33	11
Ca^{2+}	(mg l^{-1})	RANGE	9.1 – 15.0	8.1 – 25.7	6.1 – 21.4	5.9 – 33.6	9.0 – 12.7
		AVERAGE ± SD	11.7 ± 1.7	12.5 ± 2.2	10.1 ± 2.3	10.6 ± 3.5	10.2 ± 1.1
		CV (%)	14	18	23	33	11
Cl^-	(mg l^{-1})	RANGE	7.8 – 18.8	8.5 – 18.5	3.0 – 14.2	5.9 – 17.5	8.1 – 14.3
		AVERAGE ± SD	12.3 ± 3.5	12.8 ± 3.2	8.8 ± 2.4	9.1 ± 2.6	9.8 ± 1.9
		CV (%)	28	25	27	29	19
SO_4^{2-}	(mg l^{-1})	RANGE	9.7 – 17.7	10.4 – 17.2	7.3 – 18.9	7.4 – 18.8	10.0 – 13.5
		AVERAGE ± SD	13.2 ± 2.4	13.7 ± 1.9	12.1 ± 2.3	11.3 ± 2.1	11.3 ± 1.3
		CV (%)	18	14	19	19	11

S*: interstitial water at side channel
D*: interstitial water at dried up channel

Table 2. Concentrations in dissolved inorganic nitrogen (DIN), phosphate (DIP) and soluble reactive silicate (SRSi) in river, interstitial, TAMARI and WANDO waters.

			RIVER	INTERSTITIAL		TAMARI	WANDO
				S*	D*		
DIN	(µM)	RANGE	23 – 150	1 – 173	1 – 173	1 – 642	35 – 76
		AVERAGE ± SD	77 ± 27	72 ± 33	79 ± 37	77 ± 65	60 ± 14
		CV (%)	35	46	47	84	23
DIP	(µM)	RANGE	0.6 – 2.4	0.4 – 3.3	0.03 – 2.0	0.01 – 4.1	0.01 – 2.0
		AVERAGE ± SD	1.6 ± 0.4	2.0 ± 0.5	0.6 ± 0.3	1.3 ± 0.8	0.8 ± 0.5
		CV (%)	26	26	49	57	61
SRSi	(µM)	RANGE	186 – 291	213 – 315	112 – 284	113 – 327	186 – 270
		AVERAGE ± SD	247 ± 25	263 ± 26	222 ± 46	233 ± 31	238 ± 29
		CV (%)	10	10	21	13	12

S*: interstitial water at side channel

D*: interstitial water at dried up channel

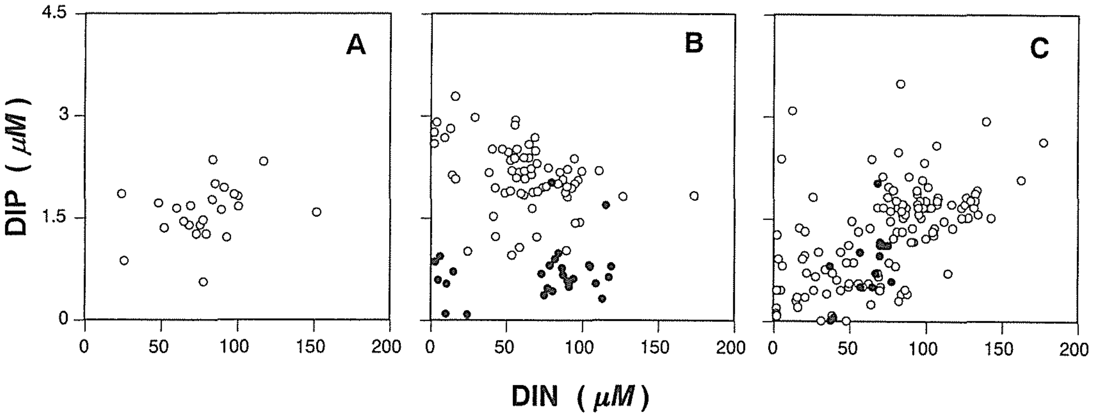

Fig. 2. Relationship between the concentrations of dissolved inorganic nitrogen (DIN) and phosphate (DIP). A: river water; B: interstitial waters in side channel (○) and dried-up channel (●); C: TAMARI (○) and WANDO (●) waters.

river water. Therefore, it is supposed that a part of interstitial (D) and TAMARI water were mixed with groundwater, precipitation and so on.

The average concentrations of DIN (sum of ammonium, nitrite and nitrate nitrogen) were similar among the river, interstitial (S), interstitial (D), TAMARI and WANDO waters (Table 2). The concentrations of DIN in both interstitial (D and S) and TAMARI water, however, varied greatly compared with those in river waters. Very low concentrations of DIN were often observed in both interstitial (D and S) and TAMARI waters. The concentrations of phosphate (DIP) in the interstitial (S) waters were in a similar range in river water, whereas they were low in the interstitial (D), TAMARI and WANDO water and varied greatly. As can be seen in Fig. 2, the ratios of DIN to DIP in the interstitial waters fluctuated widely. The ratio in the TAMARI and WANDO waters, however, showed similar values. This suggests that for a sand bar system biogeochemical processes in relation to removal of nitrogenous and phosphorus compounds were different between subsurface waters (interstitial water S and D) and surface waters (TAMARI and WANDO).

The present results indicate that concentrations of the biogeochemical constituents and their fluctuation are different among the interstitial (S), interstitial (D), TAMARI and WANDO water, respectively. Thus, the biotic and abiotic processes related to the dynamics of each biogeochemical constituent vary heterogeneously in the sand bar system.

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