THE CHARACTERISTIC CHANGE OF FINE PARTICULATE ORGANIC MATTER DUE TO A FLOOD IN THE NANAKITA RIVER

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Sediment sampling was conducted at three locations before and after a flood in the Nanakita river. The sediment samples were analyzed to obtain the information on the particle size distribution, the amount of resuspendable fine particulate organic matter (FPOM) available on the bed, and the composition of the basic nutrients, carbon, nitrogen and phosphorous, in the FPOM. The data suggest that there is an equilibrium state in which the amount of FPOM on the bed is constant in the low flow condition. The behavior of FPOM is found to show strong locality; the amount of FPOM on the bed increases during floods at some locations while it decreases during floods at other locations. In the analysis of nutrients and the microscopic observation, it is suggested that FPOM accumulated on the bed during floods is directly originated from the terrestrial area. FPOM that accumulated in the sediment after flood at all locations are found to be gradually changed in size and composition because biological activities are in process and dominant in the low flow condition.

Key Words: *sediment, fine particulate organic matter (FPOM), resuspendable solid, Stoichiometry Ratio*

1. INTRODUCTION

Particulate organic matter (POM) in streams and rivers is an important energy source that supports much of the community metabolisms. The POM is commonly separated into size classes: (a) coarse particulate organic matter (CPOM, > 1 mm), which consists of large woods and foliages from terrestrial and aquatic vegetation and animals, and (b) fine particulate organic matter (FPOM, range, 0.5 μm – 1 mm), which consists of fragments of CPOM, and aggregated dissolved organic matter (DOM, < 0.5 μm)[1]. Once the CPOM from the terrestrial area has entered streams, it undergoes biological, chemical and mechanical degradation[2]. As processing proceeds, the amount of CPOM decreases along streams, which causes the increase in the FPOM downstream. As a result, FPOM is important for distributing energy and the associated nutrients within streams. Additionally, POM is also important for controlling the dynamics of contaminants because of its affinity for hydrophobic organic compounds[3]. Understanding the relationships between downstream transport and sedimentary storage of POM is therefore critical to study of ecosystem processes as well as the characteristics of the fate and effects of contaminants.

Most importantly, at any given point along a stream, it is not known where the constituents of the carious POM categories originated, or whether the fines downstream are actually breakdown products from the CPOM upstream, generated or cycled from close upstream sources, or derived from DOM. Though numerous models have been developed to predict particle transport in streams, the exchange between the bed (storage) and the water column (transport) has not been clarified. Several reports make no clear distinction between organic matter that passes directly through a reach and material stored within the reach[4]. It is sometimes assumed that nearly all POM in suspension remains in suspension and that materials on the stream bottom remain static. On the other hand, most practical transport models of POM remain to be empirical relations between stream flow and entrainment from the bed. In this study, we examined the existence of FPOM on the riverbed compared with the particles suspended in the water column. We also performed the experiments using the sediments in the Nanakita river to quantify the amount of resuspendable FPOM, and determined the composition of the basic nutrients, organic carbon, total nitrogen and total phosphorus in order to find the origin of FPOM.

2. STUDY AREA

The Nanakita River is about 45 km long with a drainage area of 200 km^2. This study focuses on the area from 4 to 17 km upstream of the river mouth as shown in Figure 1. The bed slope of the Nanakita river is about 0.0016 in the relatively upstream reach and about 0.0003 in the lower reach as shown in Figure 2. The water discharge of the Nanakita River, which has been measured and recorded by Miyagi Prefecture at Ichinasaka, shows rather small variation from January to June. The water discharge fluctuates due to rain and snow from the end of June to December. The physical, chemical and biological characteristics of the furthest downstream reach are known to be influenced by the tidal current and the salinity intrusion[5].

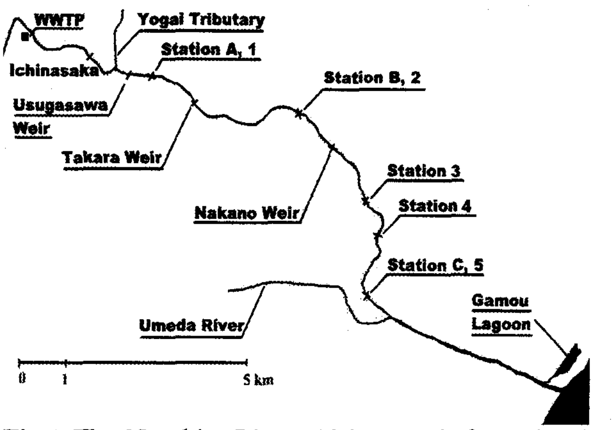


Fig.1 The Nanakita River, 15-km reach from the river mouth: 1-5 are the stations collected the sediment for size distribution studies, A,B,C are the stations collected the sediment for Resuspendable FPOM experiments

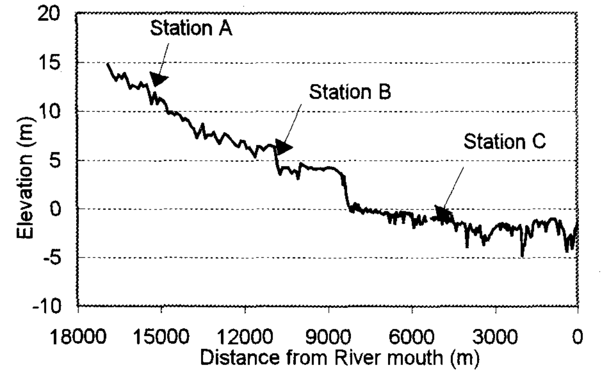


Fig.2 Topographical profile of the Nanakita Riverbed

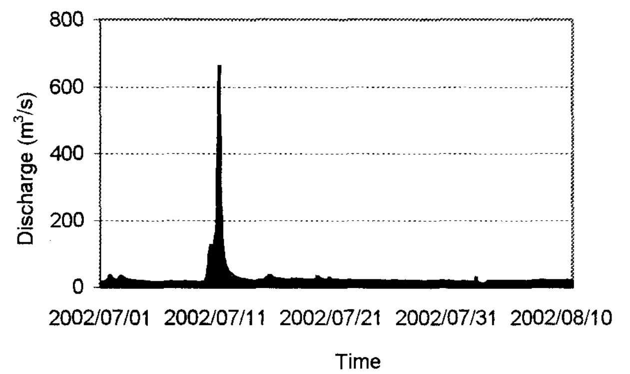


Fig3. The water discharge measured at Ichinasaka from 1 July to 10 August 2002

3. METHODOLOGY

3.1 Sediment size distribution

In order to obtain the general information on the sediment size distribution, the river water and the sediments were collected at five points, Station 1 to 5, along the Nanakita River as depicted in Figure 1, by using core sampler with an inner diameter of 7 cm. The sediment samples were sliced at several depths, and sieved in water with 74 μm sieve. The particles left on the filter were dried at 105 °C and the particle size distribution was determined by 1,000-90 μm sieves. The filtrated slurry that consist of particles smaller than 74 μm were analyzed by Microtrac HRA x 100 Automated Small Volume Recirculator.

3.2 Experiments and analysis of sediment and resuspendable FPOM

In order to obtain the information on the temporal and spatial variation of FPOM, sediments were sampled at three stations, A, B, and C, along the Nanakita River, on 9 July, 17 July, 26 July and 2 August, 2002. The hydrograph around the sampling days is shown in Figure 3. The daily average water discharges at Ichinasaka were 14.15, 22.01, 19.12 and 14.84 m^3/s on the days of data collection described above, respectively.

A flood occurred due to typhoon on 10 and 11 July 2002 that resulted in the maximum water discharges of 144.28 and 661.99 m^3/s, respectively. It is possible to assume the condition on 9 July as a low flow condition, 17 July as a condition "just after a flood", 26 July and 2 Aug as a condition "approaching the low flow condition".

Sediments were collected at three stations by using core sampler with an inner diameter of 7 cm. The surface layer, 0-1 cm, of the sediment, from 3-core sampler from each station, which represents the surface sediment material, was put into the 1,000 ml bottle. The bottle was filled with 700 ml tap water and shook for 30 seconds. Slurry that consists of water and resuspendable fine solids was taken immediately and kept in a cool storage under 5°C until analyzed (but normally slurries were treated within 24 hours after sampling).

Slurries from experiments were filtered with 47 mm Whatman Glass Microfibre Filters GF/C, which had been preignited at 105 °C. An adequate volume, usually 10-30 ml, was filtered under high pressure. The particles filtrated on the filter paper were dried at 105 °C for at least 2 hours and then weighted by Shimadzu LIBROR AEG-220G to determine Suspended Solids (SS) which represent the availability of resuspendable solids. The filtrated particles was analyzed by Technicon Auto Analyzer II to determine Total Nitrogen (TN) and Total Phosphorus (TP) which stand for Particulate Nitrogen (PN) and Particulate Phosphorus (PP) referred in this study respectively. Organic Carbon that composes resuspendable solid, which is called Particulate Organic Carbon (POC) in this study was determined by Shimadzu TOC-5000A Total organic Carbon Analyzer. Particle size distributions of Resuspendable FPOM in slurry also analyzed by Microtrac HRA x 100 Automated Small Volume Recirculator.

3.3 The analysis of terrestrial soil and vegetation

In order to collect additional information on the origin of the FPOM transported in the Nanakita river, terrestrial soil samples were collected at four locations 35-40 km upstream from the river mouth of the Nanakita River. Soil was sampled with the use of a core sampler with an inner diameter of 6.5 cm. The samples were sliced with several depth intervals. The sliced samples were dried at 105 °C for 16 hours, and ground before determined POC, PN and PP by the same methods mentioned in 3.2.

4. RESULTS AND DISCUSSION

4.1 The general characteristics of the sediment size in the Nanakita river

The sediment along the Nanakita river is composed of a heterogeneous collection of particle types, both inorganic and organic matter. Figure 4 shows the sediment particle size distribution from five stations depicted in Figure 1. The size ranges from smaller than silt (2-60 μm) to gravel (> 1000 μm).

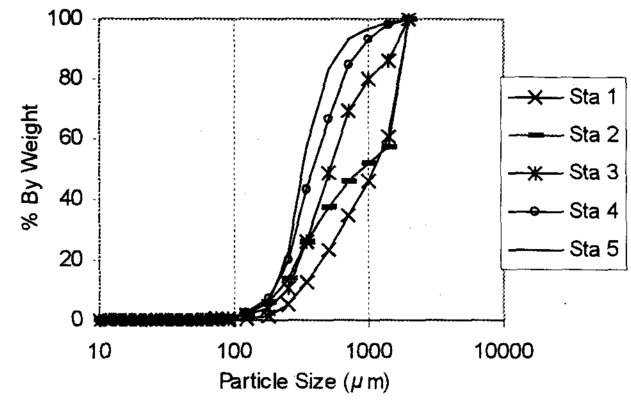


Fig.4 The particle size distribution of the sediment collected at the 5 stations, which depicted in Figure 1

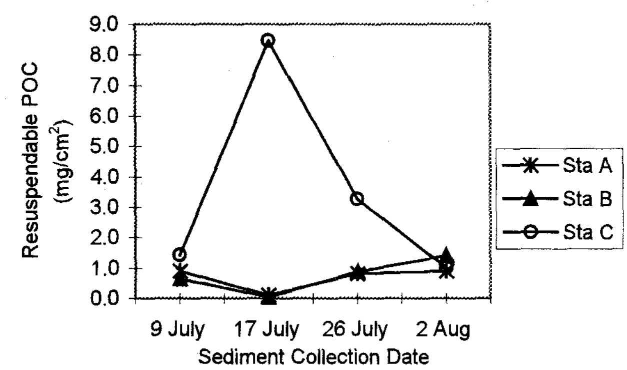


Fig.5 Temporal and spatial change of the availability of resuspendable POC on unit area of one centimeter of riverbed

The results of the experiments revealed that the bed material available for resuspension ranges from 0.8 to 400 μm in size, and that there is only a limited amount of resuspendable fine particles on the riverbed.

4.2 Temporal and Spatial variation of FPOM

The amount of POC that composes resuspendable fine particles from each sediment sample is shown in Figure 5. Since POC has linear relationship with organic matter, it is the indicator of FPOM. The figure shows the amount of POC per unit area on the bed surface, the depth of which is 0-1 cm. In the low flow condition on 9 July before the flood, the amount of resuspendable POC was 0.918 g/cm^2 and 0.652 mg/cm^2 at stations A and B, respectively. These values decreased sharply to be 0.107 mg/cm^2 and 0.032 mg/cm^2 due to the typhoon which caused high flow condition. POC results indicated that during the flood, most of FPOM was entrained and transported to the downstream reach because of large bed shear stress and discharge so that the amounts of resuspendable FPOM at Stations A and B are considerably small. A completely different tendency was observed at Station C, where the amount of resuspendable POC increased sharply from 1.444 mg/cm^2 on 9 July to 8.480 mg/cm^2 just after the flood. This different tendency may be caused by the difference of bed slope. While the bed slopes at stations A and B in the upstream reach are approximately 0.0016, station C has a considerably small bed slope of 0.0003. It is suggested that a large amount of FPOM transported from the upstream was accumulated in the furthest lower reach because of the small bed shear stress.

On 26 July and 2 Aug, the amount of resuspendable POC at stations A and B increased and reached the level comparable to the low flow condition on 9 July. Meanwhile, the amount of POC at station C decreased to reach 3.273 and 1.023 mg/cm^2 on 26 July and 2 Aug., respectively.

It is natural that the amount of FPOM recovers to the level in the low flow condition because discharge is reduced after the flood at stations A and B. However, it is not easy to explain why the amount of FPOM decreased to the low flow level at station C. These observed results could not be clearly explained based on the data we have for the present.

Several possibilities can be thought. One is the tidal condition at the furthest station. There is the possibility that tidal motion gradually transports FPOM to further downstream. Another possibility is that some of deposited materials might be transported into deep sediments via intragravel flow[6]. There is also a possibility that this is caused by biological activities. This phenomenon needs to be further studied in future.

4.3 Stoichiometry of carbon, nitrogen and phosphorus in Resuspendable FPOM

In the sediment experiments, we also analyzed the composition of the basic nutrients, organic carbon, nitrogen and phosphorus, of resuspendable FPOM. Figures 6(a), (b) and (c) present the percentage of POC, PN and PP included in resuspendable solids. The contents of the three compositions are uniform among three stations, and the average contents of POC, PN and PP are 6.4, 0.6 and 0.1, respectively, in the low flow condition. The contents changed drastically at station C on 17 July; the content of POC increases to be 11 while PP decreases to be 0.007. These changes suggest that the particle types at station C changed after the flood.

Figures 6(d), (e) and (f) show the weight ratios between carbon and phosphorous, carbon and nitrogen, and nitrogen and phosphorous included in the resuspendable solid. The C:P weight ratio of the bed material ranges from 27 to 76, and the N:P ratio

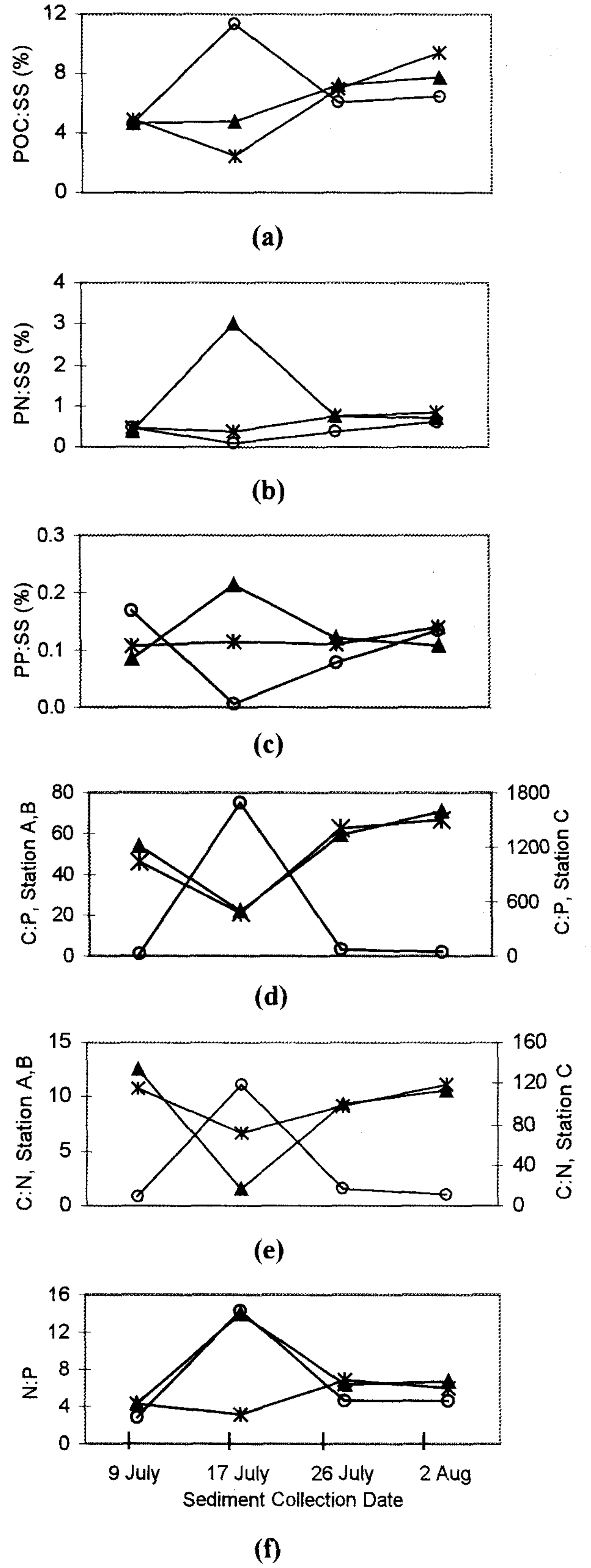


Fig.6 Temporal and spatial variation of the quality of resuspendable FPOM;
—*—Station A, —▲— Station B, —o— Station C
a) POC:SS (%), b)PN:SS (%),
c) PP:SS (%), d) C:P ratio by weight,
e) C:N ratio by weight, f) N:P ratio by weight

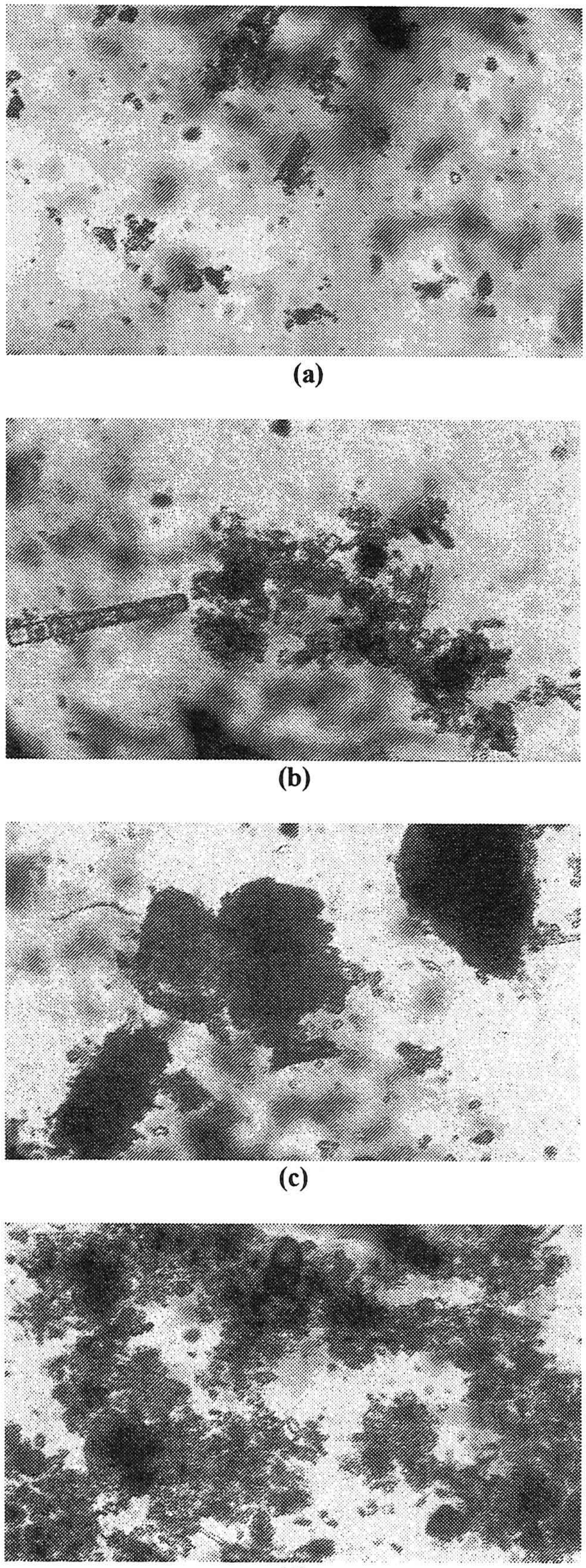
ranges from 2.8 to 6.8 in the low flow condition; thus, the average C:N:P ratio is about 43:4:1. It shows only a slight deviation from the Redfield Ratio that is 41:7.2:1. ASLO (1993) summarized that newly produced autothonous organic matter present the C:N:P ratio that sometimes differ from the Redfield Ratio because of the limitation of nutrient status of the ecosystems[7]. Goldman et al. suggested that a range of C:P ratio from 29:1 to 58:1, and N:P from 4.5:1 to 9:1 are still consistent with the concept of uniform chemical composition[8]. Thus, the results present that autothonous particle that is produced within the river ecology is dominant in the sediment during the low flow condition.

However, the C:P ratios became 21, 22 and 1692 at stations A, B and C, respectively, on 17 July whereas the C:N ratios also show considerably different trend on 17 July, which were 7, 2 and 118 at stations A, B and C. These weight ratios indicate that the organic matter accumulated on the riverbed in the low flow condition and after the flood are different. These C:N:P ratios are found to be comparable with the composition of forest soils obtained in the analysis of the terrestrial soil and vegetation as illustrated in Table 1. The terrestrial soil, especially surface soil, and vegetation are rich in C, but low in P. The ratio is characterized by the dominant species of vegetation around the site. For example, C:N:P ratio of the surface soil is 176:0.019:1 where Cedar is dominant, 148:4:1 where Reed is dominant, and 26:1.2:1 where grass covers. These results suggest that fine particulate solids found in station C just after the flood are originated directly from the terrestrial area.

4.4 Microscopic observation of resuspendable FPOM

The resuspendable solid sampled on 17 July and 26 July were observed by the use of microscope in order to identify solid types.

The microscopic photographs in Figure 8 show a significant difference of the characteristics of the FPOM between 17 and 26 July at stations A and C. The samples on 17 July at stations A and B present the considerably small amounts of micro algae and detritus, but they change to present a greater amount of phytoplankton, diatom and other living microorganisms on 26 July. While the sample at station C on 17 July proves to be mainly composed of relatively large allochthonous particles, but it presents the mixing of the fragments of terrestrial debris, algae, diatom, bacteria, and other living microorganisms on 26 July. These changes indicate the biological activities are in process and dominant in the sediment during the low flow condition.



(a) (b) (c) (d)

Fig.7 Scanning photomicrographs of sediment particles - (100*for all) from:
a) Station A, 17 July 02, b) Station A, 26 July 02, c) Station C, 17 July 02, d) Station C, 26 July 02

Table 1 Chemical composition of soils from the terrestrial area of the Nanakita river

Dominant Species of Plant	Soil Sample Layer	POC:SS %	PP:SS %	PN:SS %	C:P	C:N	N:P
Cedar	0-2 cm	15.4565	0.0077	0.0016	176.289	9488.162	0.019
	5-10 cm	9.5966	0.0038	0.4241	155.999	22.630	6.893
	10-15 cm	3.9951	0.0019	0.2587	91.247	15.444	5.908
	15-20 cm	1.2385	0.0006	0.0847	50.667	14.625	3.464
Chestnut	0-1 cm	18.0360	0.0139	0.0000	152.893	N.D.	N.D.
	1-5 cm	8.6596	0.0019	0.5709	199.238	15.169	13.134
	5-10 cm	6.5510	0.0013	0.4377	179.989	14.967	12.026
	10-15 cm	5.1672	0.0005	0.3747	221.696	13.790	16.077
	15-20 cm	4.7137	0.0005	0.3144	206.606	14.994	13.779
Reed	surface	22.5809	0.0232	0.6150	148.222	36.718	4.037
	0-5 cm	0.7687	0.0012	0.0193	22.222	39.830	0.558
	5-10 cm	1.6285	0.0013	0.1535	45.225	10.607	4.264
	10-15 cm	1.5696	0.0014	0.1298	41.480	12.089	3.431
	15-17 cm	2.0000	0.0016	0.1384	50.395	14.448	3.488
Grass	0-5 cm	0.8485	0.0011	0.0400	26.044	21.214	1.228
	5-10 cm	1.2076	0.0012	0.0976	34.935	12.375	2.823
	10-15 cm	1.3750	0.0012	0.0815	39.595	16.870	2.347

N.D= Not Detected

5. CONCLUSIONS

Sediment sampling was conducted at three locations before and after a flood in the Nanakita river. The sediment samples were analyzed to obtain the information on the particle size distribution, the amount of resuspendable fine particulate organic matter (FPOM) available on the bed, and the composition of three basic nutrients, carbon, nitrogen and phosphorous, in the FPOM.

The results of the analyses suggest that there is an equilibrium state in which the amount of FPOM on the bed is constant in the low flow condition. The behavior of FPOM is found to show strong locality; the amount of FPOM on the bed increases during floods at some locations while it decreases during floods at other locations.

The results of the analyses of nutrient compositions and the microscopic observation of fine particulate matter suggest that autothonous particle is dominant in the sediment due to the biological activities are in process during the low flow condition while FPOM that accumulated during floods is directly originated from the terrestrial area.

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(Received September 30, 2002)