EVALUATION OF SUSPENDED-SOLID SOURCE IN TAMAGAWA RIVER WATERSHED WITH CONTINUOUS TURBIDITY MONITORING AND X-RAY FLUORESCENCE ANALYSIS

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Abstract: For comprehensive management of sediment of inner bays, we attempt to evaluate suspended-solid (SS) sources in the watershed of the Tamagawa River, a large river flowing into Tokyo Bay, Japan. For this purpose, we continuously monitored turbidity at four stations and conducted X-ray fluorescence (XRF) analysis of riverbed material obtained at many stations. The coefficient *b* in sediment rating curve in low-flow conditions was found to be larger than that in high-flow condition in mountain rivers like the Akikawa River. The results reveal that 67% of total SS transports in the Tamagawa River is transported from mountain rivers and other SS transports are mainly supplied from riverbed materials that are picked up under high-flow conditions. These tendencies are also confirmed through the XRF analysis of bed material.

Keywords: suspended solid; sediment transport; sediment rating curve; Tamagawa River; X-ray fluorescence analysis

1 INTRODUCTION

Water quality problems in inner bays are generally caused by not only increases in pollutant load from the watershed but also loss of mud flat that may have a significant function in water purification. Since fine sediments contain nutrients and organic matter, it is important to understand behavior of suspended solids (SS) over the watershed for comprehensive management and control of sediment and water quality in inner bays. Suspended-sediment transports in high-flow conditions are appreciably larger than those in relatively low-flow conditions, so it is useful to continuously monitor turbidity, which is closely related to suspended-sediment concentration. However, there have not been enough monitoring data of SS over the whole watershed to evaluate SS behavior appropriately.

For comprehensive management of sediment of inner bays, we attempt to evaluate SS sources in the watershed of the Tamagawa River, a large river flowing into Tokyo Bay, which is a well-known eutrophic inner bay in Japan. Behaviour of sediments and its source in the Tamagawa River and Tokyo Bay were examined by Takada et al. (1992) and Suzumura and Kamatani (1995). However, there were few data about SS transports in the Tamagawa River and other influent rivers into Tokyo Bay. To obtain such data, we continuously monitored turbidity at four stations in the watershed of the Tamagawa River by using optical turbidity sensors. We also performed X-ray fluorescence (XRF) analysis of riverbed material obtained at many stations. By using these two types of results, we evaluate the source of the SS.

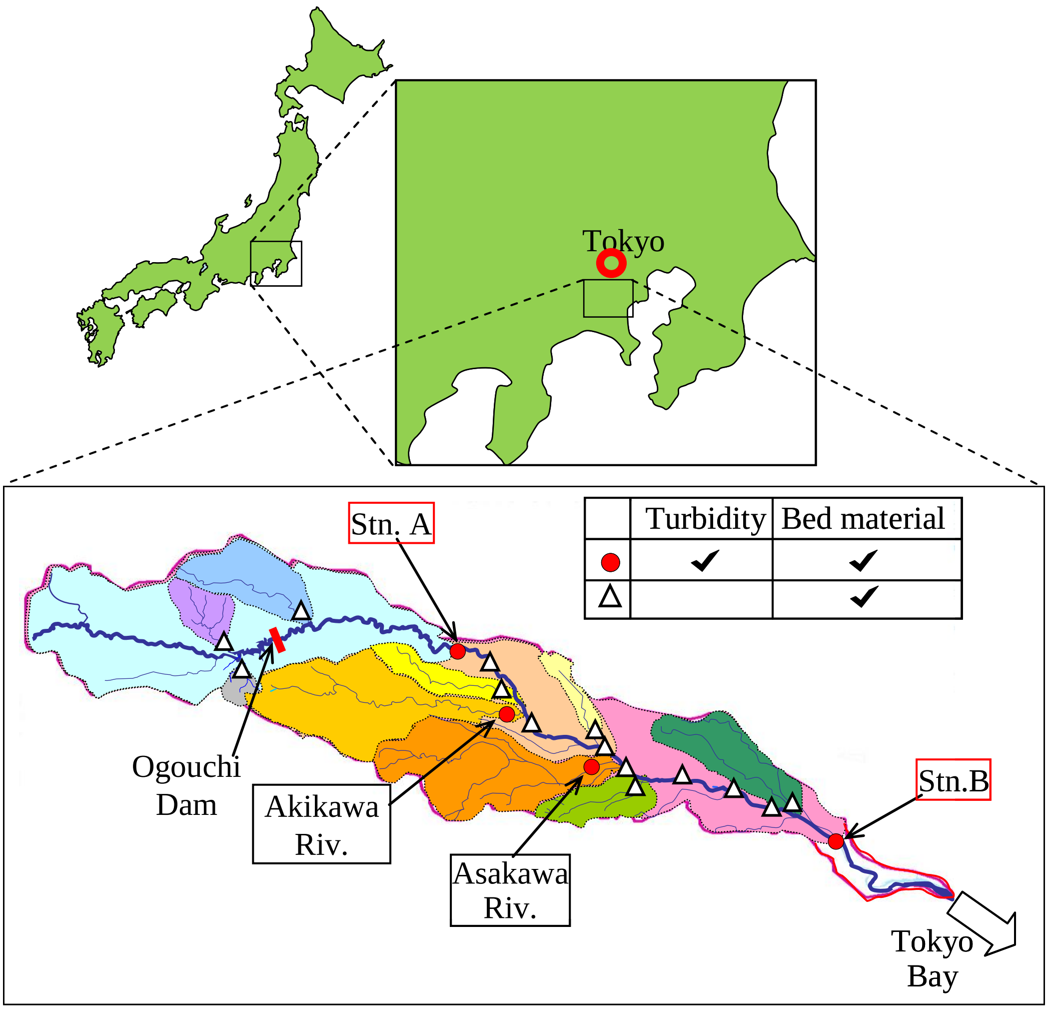

Figure 1 Maps of the Tamagawa River and locations of field measurements.

2 OUTLINE OF FIELD MEASUREMENTS

2.1 Outline of Tamagawa River and its watershed

The Tamagawa River, which was chosen for the field site, is shown in **Fig. 1**. The length and watershed area of the Tamagawa River are about 138 km and 1240 km^2, respectively. The Ogochi Dam with the watershed area of 226 km^2 was constructed in the upstream reach of the Tamagawa River. Large branches of the Tamagawa River are the Akikawa and Asakawa Rivers, in which catchment areas are 170 km^2 and 155km^2, respectively. The tributaies are mainly in forests in the watershed and are categorized as mountain rivers. Other tributaries like Ogurigawa and Nogawa Rivers flow in urban districts and hence are seen as urban rivers.

2.2 Continuous turbidity monitoring

As shown in **Fig. 1**, the field sites for turbidity monitoring in the Tamagawa River watershed were positioned at two stations of the main stream (Stns. A and B) and two tributaries (the Asakawa and Akikawa Rivers). At these points we installed optical turbidity sensors (Compact-CLW of Infinity-Turbi, JFE Advantech Co. Ltd.) with a wiper for cleaning the optical sensor to conduct a long-term observation. The meausurement periods at Stns. A and B were from July 11 to November 1, 2011, and from July 31, 2006, to November 1, 2011, respectively. The periods in the Akikawa and Asakawa Rivers are from August 16 to December 8, 2010 and from September 3 to November 4, 2010, respectively. We also installed an automatic water sampler (Water sampler 6712, Teledyne ISCO) at Stn. B to collect river water samples during flooding events. SSs of water samples were analysed to obtain the relationship between turbidity and SS in which we use SS[mg/L]=1.79*turbidity[FTU].

Using these data, we evaluated sediment rating curves expressed in the following equations,

$$L = aQ^b, \qquad (1)$$

where L means SS transport, Q is river discharge, and a and b are coefficients. To compare the L-Q relationship among several rivers with different watershed areas, the specific SS transport L' and specific discharge Q', where L and Q are both divided by watershaed area A, are used here.

2.3 Analysis of riverbed material

To evaluate SS source in the watershed of the Tamagawa River using another approach, we collected samples of riverbed material at 18 stations shown in **Fig. 1** in 2010 and 2011. Samples of riverbed materials were divided into fine and coarse sediments, and the XRF analysis of divided samples was peformed by using a fully automatic X-ray fluorescence spectrometer. The content percentage of element component was computed on the basis of the fundamental parameter method. From these results, we examine the source of SS by using continuous turbidity monitoring data.

3 RESULTS AND DISCUSSION

3.1 Relationship between specific SS transport *L'* and specific discharge *Q'*

Figure 2 compares the SS transports among rivers by showing the correlation between specific SS transport L' and specific discharge Q' at Stns. A and B of the main stercam and two tributaries (the Asakawa and Akikawa Rivers). The figure depicts results in the Kandagawa River, a typical urban river flowing through Tokyo. The figure also shows the moving-averaged data for the above specific SS rating curves. The observed results indicate that specific SS rating curves in Stns. A and B are similar to those in two tributaries, while the specific SS transport in the Tamagawa River is almost totally larger than that in the Kandagawa River under the same specific discharge. The specific SS rating curves indicate that a coefficient b in SS rating curve in high-flow conditions is larger than that in low-flow conditions for Stn. B and the Kandagawa River. The opposite tendency for the coefficient b was found in mountain rivers such as Stn. A (main stream) and two tributaries, mainly due to first flash phenomenon, which rapidly increases material transport in the rising stage of flooding.

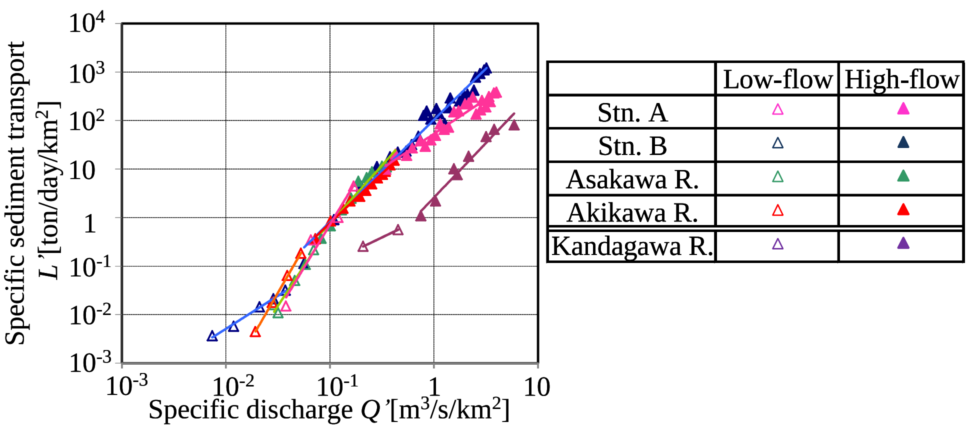

Figure 2 Relationships between specific SS transport L' and specific discharge Q' in the Tamagawa and Kandagawa Rivers.

3.2 Sediment budget in the watershed of the Tamagawa River

Figure 3 displays the cumulative discharge and SS transports in the Stn. B of the main stream from 2006 to 2009 using the above sediment rating curves. The results at Stn. B are separated into the results at Stn. A, the Akikawa River, the Asakawa River, and other areas. While the discharge increased gradually, the SS transport increased rapidly only under flooding events. In particular, the appreciable increase in SS transports was observed during typhoon no. 0709, which caused the largest flooding in the five years studied. The large amount of SS transports at Stn. B was occupied by those at Stn. A, the Akikawa River, and the Asakawa River. This means that the SS transports in the watershed of the Tamagawa River are mainly from the watershed of mountain rivers.

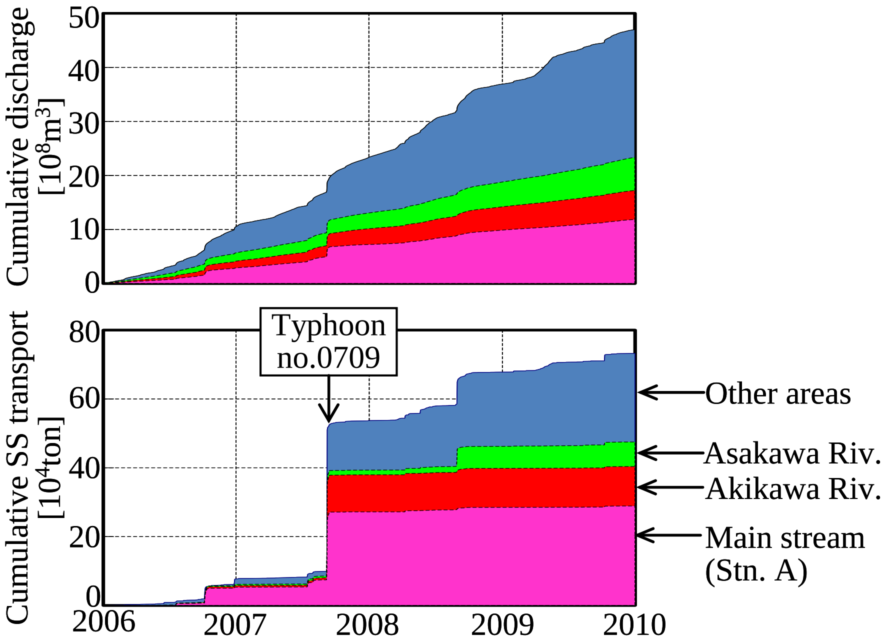

Figure 3 Cumulative discharge and SS transport from 2006 to 2009.

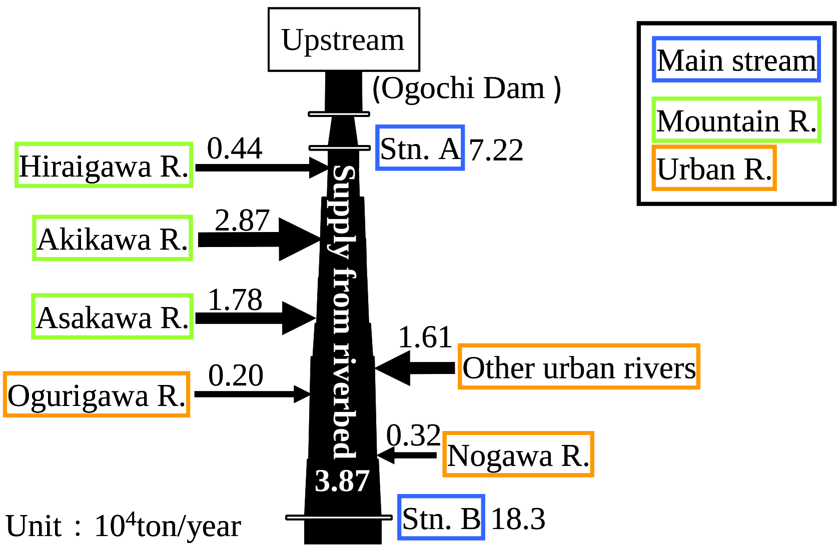

Figure 4 SS budget in the watershed of the Tamagawa River.

Figure 4 illustrates SS budget in the watershed of the Tamagawa River. Yearly averaged SS transports from 2006 to 2009 in the main stream and several tributaries are shown here. The SS transports at Stns. A and B were $7.2*10^4$ and $18.3*10^4$ ton/year respectively. In contrast, the total SS transports in mountain tributaries (the Akikawa, Asakawa and Hiraigawa Rivers) and in urban tributaries were $5.1*10^4$ and $2.1*10^4$ ton/year, respectively. The SS transports at Stn. B were not equal to the summation of SS transports at Stn. A and all tributaries. This difference in the SS transports was $3.87*10^4$ ton/year and was considered as supply from river bed. The results also reveal that 67 % of total sediment in the Tamagawa River was transported from mountain rivers and other SS transports were supplied from the riverbed materials that are picked up under high-flow conditions.

3.3 Study of compotision of riverbed material

Figure 5 shows the streamwise variations for Fe (Iron) content of fine sediments and gravel in the main stream and of fine sediments in urban and mountain tributaries. Although Fe content of fine sediment in the main stream decreased wholly in the streamwise direction, the increase and decrease in the Fe content in the main stream are similar to those in mountain and urban tributaries. This means that the fine sediments of riverbed materials are influenced by those of tributaries. On the other hand, the Fe content of gravel was lower than that of fine sediments in the main streams and all tributaries. The Fe content of fine sediments in the downstream reach of the main stream were lower than those in the upstream reach and tributaries. These facts indicate that the low Fe content of fine sediments in the downstream reach may be affected by that of gravels, showing that the riverbed gravels are supplied to fine sediments that are composed of SS. Thus, the SS sources are composed of not only mountain rivers but also riverbed materials.

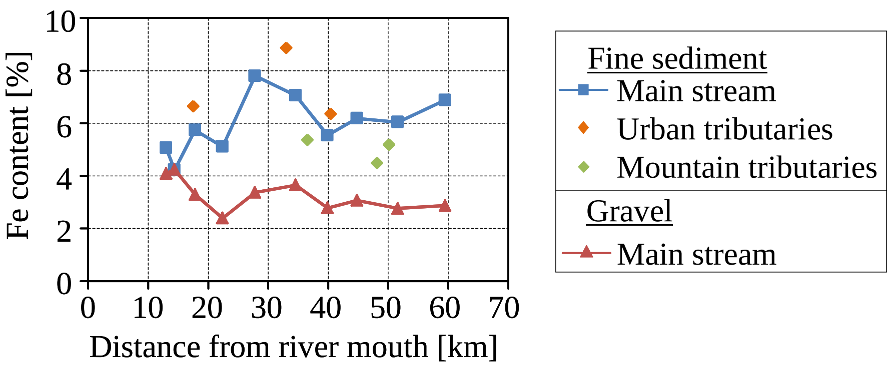

Figure 5 Streamwise variations for Fe content of fine sediments and gravel in the main stream.

4 CONCLUSIONS

To examine the SS source of the Tamagawa River, Japan, we continuously monitored turbidity and conducted XRF analysis of riverbed material in the watershed of the Tamagawa River. The main conclusions in the present study are as follows:

(1) The SS transports of the mountain tributaries were larger than those in urban rivers. The specific SS rating curves indicate that a coefficient *b* in SS rating curve in high-flow conditions is larger than that in low-flow conditions for Stn. B and the Kandagawa River. The opposite tendency for the coefficient *b* was found in mountain rivers such as Stn. A (main stream) and two tributaries, mailny due to first flash phenomenon, which generally rapidly increases material transport in the rising stage of flooding.

(2) 67 % of total sediment in the Tamagawa River was transported from mountain rivers and other SS transports were supplied from the riverbed materials that are picked up under high-flow conditions.

(3) The resuts of the XRF analysis indicate that the Fe content of fine sediments in main streams was affected by that of fine sediments in the mountain and urban tributaries and gravel in the main stream. This means that the SS sources of fine sediments are composed of not only mountain tributaries but also riverbed materials.

Hideshige Takada, Norio Ogura and Ryoshi Ishiwatari (1992), "Seasonal variations and modes of riverine input of organic pollutants to the coastal zone: 1. Flux of detergent-derived pollutants to Tokyo Bay", *Environ. Sci. Technol.*, Vol. 26, No. 12, pp. 2517-2523.

Kentaro Tanaka and Yasuo Nihei (2011), 'Suspended-sediment transports flowing into Tokyo bay with a SS monitoring network', *Annual Journal of Hydraulic Engineering*, Vol. 55, pp.S_1327-1332 (in Japanese).

Masahiro Suzumura and Akiyoshi Kamatani (1995), "Origin and distribution of inositol hexaphosphate in estuarine and coastal sediments", *Limnol. Oceanogr.*, Vol. 40, No. 7, pp. 1254-1261.