# ACCUMULATED SITUATION OF ORGANIC MATTER AT SABO DAM AREA AND THE PROCESSES OF INFLUENCE ON WATER ENVIRONMENT IN TOHOKU REGION

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**ABSTRACT**

It had been reported that water quality was changed by the effect of Sabo-Dams. Actually a Sabo-Dam has some factors that influence on water environment. So, several factors like amount of retention, situation of organic matter (LPOM, CPOM) accumulated, total Fe and $SO_4^{2-}$ were surveyed in Tohoku Region of Japan. The amount of LPOM retention was 10-$10^2$ kg dry weight per day. Moreover, it was observed that CPOM was accumulated in stratified situation and reaction of reduction might occur in the accumulated sediment. Actually, the concentration of Fe and $SO_4^{2-}$ was changed between upstream and downstream side of the dams. However the differences were not same to every dam investigated, it was assumed that the magnitude is depended on situation of degree of sediment-brimmed and water level fluctuated. Additionally, it was considered from the characteristic of investigated results in Fe and $SO_4^{2-}$ concentration that there occurred water exchange in hyporheic zone. Finally, some issues were become clear toward the next stage of this study.

**KEYWORDS: organic matter, erosion control dam, mountainous stream, anaerobic condition**

## INTRODUCTION

A Sabo Dam is constructed to block the sediment such as sand or gravel and to retain it for erosion control. However, a lot of large particle organic matter (leaf litter, branch, and aquatic flora and fauna, etc.) is unexpectedly accumulated in the dam at the same time in Tohoku Region. And then the stagnated period of the organic matter is so long that the organic matter is decomposed. As the result, it is supposed that these decomposition processes are influencing water quality accompanying at dam vicinity. In fact, water quality has changed between upstream and downstream side of some investigated dams. On the other hand, it is a fact that the influence of above-mentioned phenomena is declined gradually even almost negligible in other dams those are filled fully with sand and gravel.

Generally, when organic matter is decomposed under anaerobic condition like near the bottom of lake, the concentration of hydrogen sulfide ($H_2S$) and iron sulfide (FeS) and $Fe^{2+}$ will be increased. Then they are changed to $SO_4^{2-}$ and $Fe^{3+}$ at upper layer with available oxygen. The exchange of elements between bottom sediment and the overlying water column is of special interest, because of its significance with regard to ultimate fate of elements in lakes

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(Taylor *et al*. 1995). In Sabo Dam, the water depth is not so deep rather fractural. So it is supposed that anaerobic condition will appear under the surface of accumulated sediment. Additionally, aerobic condition will appear even under the surface in case of low water level, because of exposure to atmosphere. So some variations of differences will be observed accompanying water level. Complex phenomena are considered between stream water and accumulated sediment like hyporheic zone. Ferric hydroxide makes a streambed color dark red in downstream of a dam. Fig.6 and 7 show inundation area of a dam and water pathway. On a word, the sediment-water interfaces have not only vertical dimension but also lateral and longitudinal dimensions.

Study objects are to consider the mechanism that causes the differences of water quality between upper stream and downstream site of dam through the obtained data at the surveyed dams.

## METHOD AND SITE SELECTION

At first the accumulated situation of organic matter was surveyed. $SO_4^{2-}$ and total Fe at upstream and downstream of Sabo Dam was also investigated. Total Fe was investigated instead of $Fe^{2+}$, because $Fe^{2+}$ immediately changes to $Fe^{3+}$ under aerobic condition and $Fe^{3+}$ soon becomes any complexes. If decomposition of organic matter has influence on water quality, it will exhibit in the differences between upstream and downstream phenomena. However, on the basis of accumulated situation, seven dam sites were surveyed concerning total Fe. And at two dam sites, accumulated condition of organic matter and $SO_4^{2-}$ was surveyed. The every stream where the investigation was carried out is the first or second stream order. In this report, the investigation results concerning the processes of the influence on water quality are reported, but they are not sufficient to make the processes clear.   Using these data, working hypothesis will be considered toward next stage of the study.

## CONDITION OF ACCUMULATED ORGANIC MATTER IN SABO-DAM AND POSSIBILITY OF DECOMPOSITION

Fig.1 and Fig.2 show the difference of the value (the dry weight per day of LPOM (Litter Particulate Organic Matter (>4mm)), of upstream and downstream, which was converted from the observed value, gathered for five minutes with 4mm mesh net. The measurement was

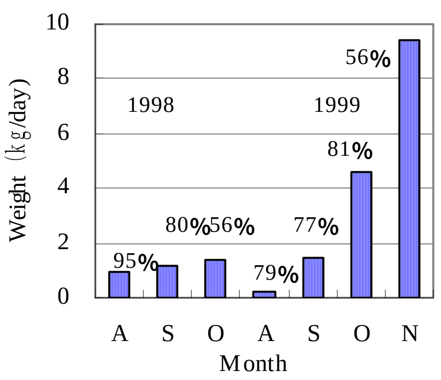


**Fig.1** Stagnated weight in dam
(LPOM；Kanosawa 4th dam)
C.A.=11.07㎞²

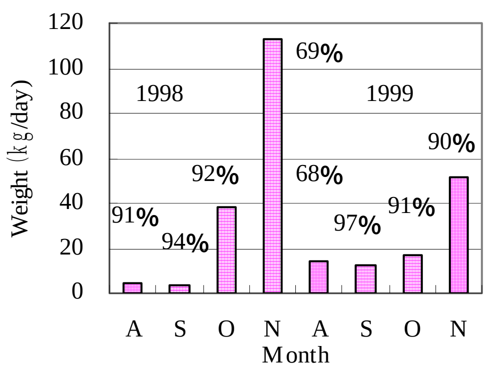


**Fig**. 2　Stagnated weight in dam
(LPOM;Maenokawa dam)
C.A.=11.95㎞²

carried out on a non-rainy day a month. Fig.1 and Fig. 2 show the values at Kanosawa-River (4th dam) and Maenokawa dam, respectively those are clear revealed that large amount of LPOM has been accumulated at the dam.

Fig.3 and Fig.4 express the accumulated condition of CPOM (Coarse Particulate Organic Matter (>1mm)(Lamberti 1996)) among the bed soil layer in each dam. It is understood that the stagnation of organic matter and soil were accumulated in stratified situation, especially at Kanosawa-River. The area goes under water in flood period and gets aerated in dry period. The vicinity of dam body is always inundated and the upper part is sometimes or often exposed with atmosphere. In addition, aerobic and anaerobic state will be repeated at the vicinity of the sediment surface at the upper part. It is suggested that a complicated influence to water quality occurs comparatively in the accumulating process more than in the time of just installation of dam and after sediment-brimmed, wherein less organic matter will be kept.

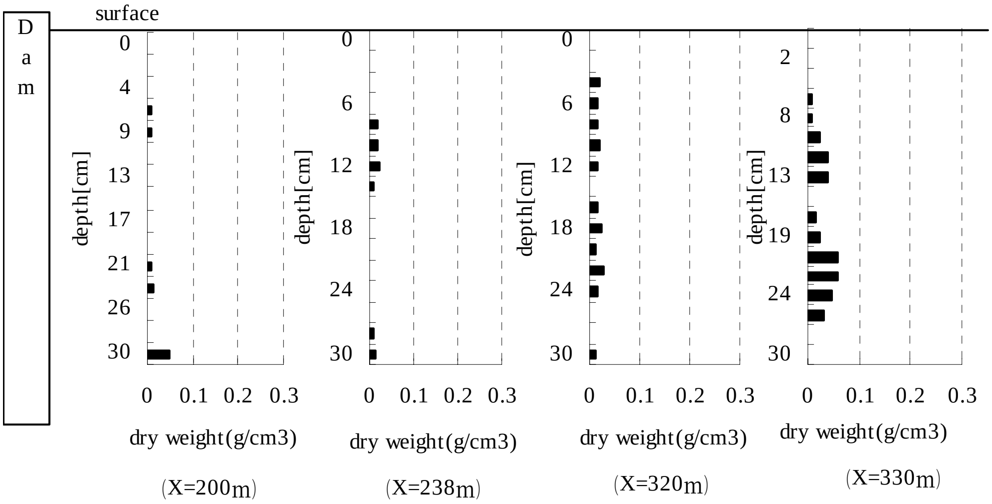


**Fig.3** CPOM in the accumulated sediment; Kanosawa 4th dam

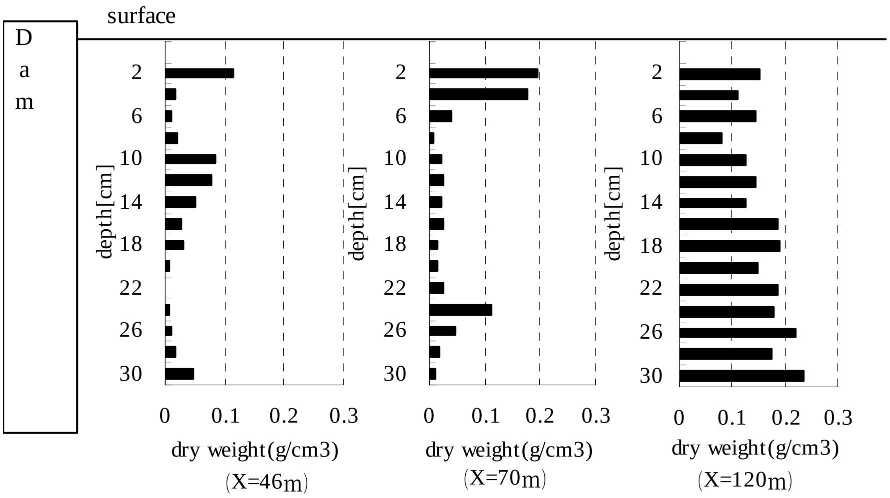


**Fig.4** CPOM in the accumulated sediment;Wasadagawa River 3rd dam

## INFLUENCE OF ACCUMULATED ORGANIC MATTER IN TOTAL Fe

Fig.5 shows the difference of the amount of total Fe between upstream and downstream side of Sabo-Dam according to the degree of sediment-brimmed situation. If the accumulated soil layer or the bottom of the inundation area is under anaerobic condition (state of reduction), iron compound will be generated. That is why, the difference of concentration of total Fe is almost zero in the case of sediment-brimmed dam in the same figure, which shows paradoxically above mentioned. Moreover, generally understanding, Fe elusion from the surface of the soil layer will be difficult after the oxidation membrane once is formed by Fe compound. And the difference of total Fe between the upper and down stream site is admitted even at the time when the inundation area decrease, so it seems that the elusion of these Fe has occurred through the water flowing in the soil layer like hyporheic zone. Otherwise, it is also possible to consider that the reaction has occurred near the dam bank body where is always inundated and higher water depth.

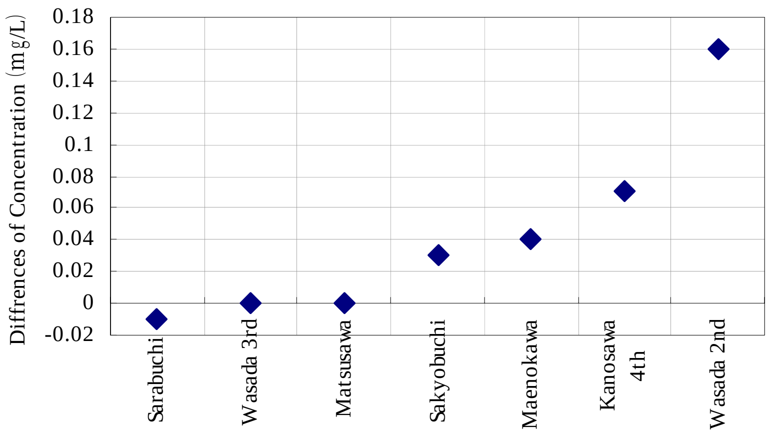


**Fig.5** Differences of the concentration of total Fe between upper and down site at each dam

Sakyobuchi dam shown in Fig.5 is in the state of sediment-brimmed, but some differences are admitted in the amount of total Fe between upper and down stream sites. In a word, it can be considered that the geographical features and magnitude of vegetation cause the difference even if it is a state of sediment-brimmed. Fig.13 and 15 in the next paragraphs are the photographs of Sabo-Dam at Wasada-gawa River and Sarabuchi-sawa, respectively. The vegetation has advanced to the riparian, and then the riverbed has recovered to a kind of natural situation in the upstream part, except changing to the smooth riverbed. The state of upper stream of Sakyoubuchi-dam (see Fig.11) is thought to be in a process toward the above situations.

## STATE OF ACCUMULATED SEDIMENT AND WATER PATHWAYS

The situation of accumulated sediment and water pathways will be introduced using the photographs as follows.

Fig.6 and 7 show the second Sabo-Dam in Wasada-gawa River. In the Sabo-Dam, sediment accumulation is advanced, but the dam did not reach to the state of sediment-brimmed. The major part of the accumulated sediment at the dam is exposed during dry season, and some water pathways are admitted among the accumulated sediment. It was confirmed that at first flow eroded the side of water pathway, and then the upper part collapsed. Moreover, after the rainfall as shown in Fig.7, the accumulated sediment sank under water and consequently a big inundation area appeared.

**Fig.6** Water pathway among accumulated sediment (Wasada-gawa River 2nd dam)

**Fig.7** Inundation area after rainy day (Wasada-gawa River 2nd dam)

Fig.8 and 9 shows the fourth Sabo-Dam in Kanosawa-River. Fig.8 is photograph of the inundated part for all time. The organic matter originated from plant stayed in the surface of the water. The side of water pathway, which is reflected in Fig.9, was eroded and collapsed with the stream flow. As for the accumulated sediment, the particle size is smaller than one in Wasada-gawa River because of the feature of the valley of sandstone and the accumulating rock. The sediment smelled like sulfide, so it was suggested that the inside of the sediment was under condition of reduction.

**Fig.8** Organic matter floating on the water (leaf litter and branch) (Kanosawa River 4th dam)

**Fig.9** Water pathway in the sediment (Kanosawa River 4th dam)

Maenokawa River (Fig.10) had wider inundation area than Kanosawa-River the fourth Sabo-Dam and Wasada-gawa River the 2nd Sabo-Dam (Fig.6), and the water pathway and the accumulated sediment can be confirmed only draughty year except upper area. When a

**Fig.10** Large inundation area (Maenokawa River dam)

**Fig.11** Local inundation spots and several pathways (Sakyobuchi dam)

long-term water shortage occurs, the erosion and the collapse of the accumulated sediment can be seen as well as above dams.

The Sakyobuchi dam is in the state of sediment-brimmed, though some local inundation spots exist in the vicinity of the bank body. Moreover, there are some water pathways (Fig.11) because the river section is wide.

Fig.12 and 13 show the third Sabo-Dam in Wasada-gawa River. It is in the state of sediment-brimmed, and the upstream part is changed to a smooth riverbed, but it is recovered with the gravel as similar to upper natural reaches. Moreover, the advancement of vegetation is seen toward the channel from the riparian (Fig.13).

**Fig.12** Wasada-gawa River 3rd dam

**Fig.13** Upper (over Fig.12) streambed condition

Sarabuchi dam (Fig.14 and 15) is brimmed with sediment and recovered to natural state similar to third Sabo-Dam of Wasada-gawa River.

By the way, the accumulated sediment is exposed in relation to magnitude of inundation and water pathways are formed by the stream flow as mentioned above. Since the erosion and

**Fig.14** Sarabuchi dam in old style

**Fig.15** Upper condition (over Fig.14) (Sarabuchi dam)

collapse of channel bank occur, thus organic matter that is decomposed and crushed in soil layer is transported to downstream along with sediment simultaneously.

## MOVEMENT OF $SO_4^{2-}$ BETWEEN ACCUMULATED SEDIMENT AND STREAM WATER

It can be speculated that there is a reduction layer, similar to lakes and marshes, near the surface of accumulated sediment in Maenokawa and other dams those have broad inundation area. In general, hydrogen sulfide $H_2S$ is generated in reduction layer and the sulfuric acid ion generates when hydrogen sulfide oxidized in stream water. Then, concerning $SO_4^{2-}$, the movement between the stream water and the accumulated sediment will be considered as follows.

Flux $q_s$ of hydrogen sulfide $H_2S$ depends on inclination of the concentration in the reduction layer. Therefore, we can assume the amount of the flux $q_s$ as

$$q_S = -a\frac{dS}{dy} = -a\frac{(S_1 - S_2)}{y_h}, \qquad (1)$$

where $a$ is diffusion coefficient; $S_1$, $H_2S$ concentration of the stream water beyond the reduction layer; and $S_2$, $H_2S$ concentration in the sediment under reduced condition.

Here, it is assumed that $S_1$ is proportion to the $SO_4$ concentration of the river water ($S_u$) because $H_2S$ will be oxidized to $SO_4$ with stream water. Moreover, flux $q$ of $SO_4$ would be proportion to the flux $q_s$ as

$$q = kq_S = -ka\frac{(mS_u - S_2)}{y_h}, \qquad (2)$$

where $S_u$ represents $SO_4$ concentration of the stream water; $y_h$ , thickness of the reduced layer with inclination of concentration; and $k$ and $m$, proportion constant. Therefore, a total movement $S_t$ of $SO_4$ can be represented as follow:

$$S_t = -ka\frac{(mS_u - S_2)}{y_h}A_s, \qquad (3)$$

where $A_S$ is area of the bottom sediment in dam. In addition, using new parameter $a_s$ which includes the thickness $y_h$ of the reduction layer, the area $A_S$ of the bottom sediment and coefficient $a$ because they are uncertain, Eq. (3) becomes:

$$S_t = -a_s(mS_u - S_2). \qquad (4)$$

The law of the mass preservation is adjusted to the upper and down site of the dam. Thus,

$$QS_d = QS_u - a_s(mS_u - S_2) \qquad (5)$$

and

$$Q(S_d - S_u) = -a_s mS_u + a_s S_2 = -AS_u + B, \qquad (6)$$

where $Q$ is flow quantity; $S_d$, $SO_4$ concentration in the downstream.

Fig.16 and 17 show the calculated results using Eq. (6). In Maenokawa River, the value of

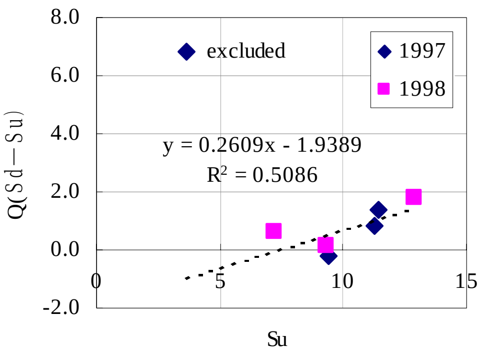


**Fig.16** Calculated results（Kanosawa 4th dam)

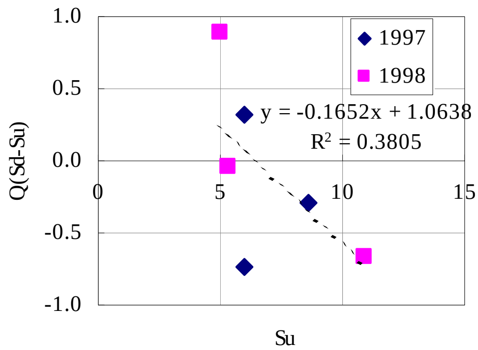


**Fig.17** Calculated results（Maenokawa）

*A* took *A*=0.165. But in Kanosawa River, the value of *A* took a minus value (*A*=-0.261), however, it is irrational because flux is assumed to be proportional to inclination of concentration and *A* should be a plus value. In a word, the phenomenon of $SO_4^{2-}$ movement is also considered that occurs between stream water and accumulated sediment not only by diffusion through the surface but also by flow exchanging through the bank side of water pathway and so on like hyporheic zone. And according to the fluctuation of water level, the depth of reduction layer and area will be changed.

From the above-mentioned study, some issues are considered for next stage of investigation as follows.

(1) Surveying the water quality of hyporheic zone with seasonal sampling because of water level and water temperature (magnitude of reduction might depend on this) changing.
(2) Surveying the water quality of the most deepest inundation area near the body of dam.
(3) Analyzing $Fe^{2+}$.

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