DISTRIBUTION OF ORGANIC MATTERS AND RELEASE CHARACTERISTICS IN DAM RESERVOIR(*)

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1. INTRODUCTION

In artificial reservoirs, sediments are accumulated naturally and also by human activities. They pass through biological, physical and chemical processes like dissolution, diffusion, re-floating and disturbed by fish. Afterwards, they are released to the water and have influence on water quality and ecosystem. The influences of sediments upon water quality vary with respect to the formulation and environmental condition and therefore, appropriate measures need to be made according to the degree of contamination.

In Korea, fish farms in reservoirs have been removed to reduce the contamination during last few years and various water quality management program to minimize the formulation of organic matters have applied continuously getting effective results. Piston coring was performed at locations where thick sedimentation was expected to examine the distribution of sediments in Daechung multi-purpose dam. The trend of release rate may be obtained because samples have been taken at same location since 1997. This result will be compared to the foreign cases and the influences of sediments to the reservoir water quality will be analyzed to use them as an effective assessment scheme.

(*)Répartition des matierès organiques et caractéristiques des lâchers dans les retenues de barrage.

2. RESEARCH METHOD

2.1. LOCATION

Daecheong multi-purpose dam is an important water resource of Korea and one of the domestic multi-purpose dams where a lot of active researches were done. This dam, whose river length is 251 km and basin area is 4,134 km2, is located at upper middle part of the Kum river. Total capacity of the reservoir is 1,490 × 106 km3 and the number of residents in the basin is about 324,000 (1998). Because there are lots of pollution sources in the basin, they are having difficulty in water quality management.

According to the BOD record of Daechung reservoir in 1998, the ratio of domestic wastewater was 37.6 %, that of livestock wastewater was 25.9 %, that of land use was 26.0 % and that of others was 10.5 % and this result showed us that the treatment of domestic wastewater and livestock wastewater should be done first. Some parts of Daechung reservoir are mainly influenced by naturally accumulated sediments and other parts are influenced by sediments caused by human activities (Figure 1). Fine particles from the upper stream were observed at the place near the dam and the Hoenam area appeared to be the most seriously influenced place by the sediments from fish farms. Comparably bigger particles were observed around the Janggegyo area.

2.2. FIELD INVESTIGATION AND METHODS

Piston coring was performed in September, 1999 and the length of the piston core was 6 m, the diameter was 66 mm, and its weight was 200 kg. The picked samples were sealed immediately at sites and carried to the laboratory and cut into two pieces using an automatic cutter. For each piece, color, texture, transformation of rock floor were investigated and recorded, and an X-ray was shot to investigate the accumulation structure.

A grab sampler was also used for release experiment and it was performed in 1997, 1998, 1999 and 2001. Picked samples were brought to the laboratory immediately to be used for release experiment and filtered reservoir water was used for the test. Water quality analysis was done for various items and the result was used as basic data.

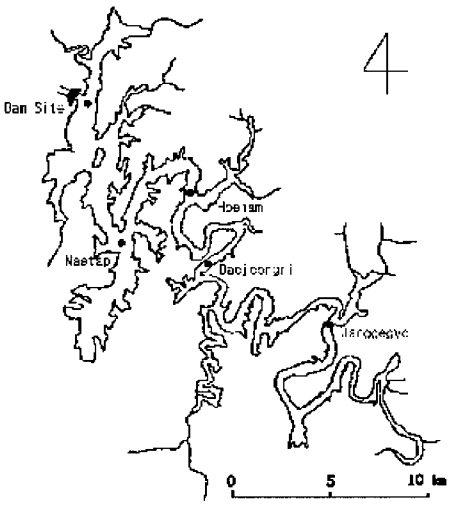

Fig. 1 Locations of sampling sites - Localisation des sites d'échantillonage.

3. RESULTS AND DISSCUSION

3.1. FORMATION CHARACTERISTICS OF ORGANIC SEDIMENTS

Formation of organic sediments in reservoirs

can be classified into two major categories : one is formed with the particles from outside of the reservoir and the other is formed with those from inside. The former flows into the reservoir with rain in most case and accumulated (Fig. 2). The particles like these varies in composition depending upon the quantity of inflow or the rainfall characteristics. Other factors include the soil characteristics of a basin and the land use.

In rainy season, turbid water flowing into the reservoir contains a lot of particles and nutrient. This forms a middle layer from the upper middle part of reservoir to the places near dam. Samples near dam appeared to be less than 10 μm in size. Particles of 10 μm and 5 μm take 9 days and 36 days, respectively to sediment through 40 m of steady water·layer when 'stokes formula' is applied. Concentrations of SS increased to 58.5~73.3 mg/l from 0.2~1.2 mg/l when turbid water flowed in to the reservoir during the rainy season in 1999 (Table 1). Concentrations of COD and T-N increased very little comparing to that of SS, but that of T-P increased up to 0.09 mg/l. This shows that turbid water contributes significantly to the formation of sediments and eutrophication.

Causes of contamination from outside include the results of human activities like fish farming. In 1990, there used to be over 17 fish farms in Daechung reservoir, but all of them have been

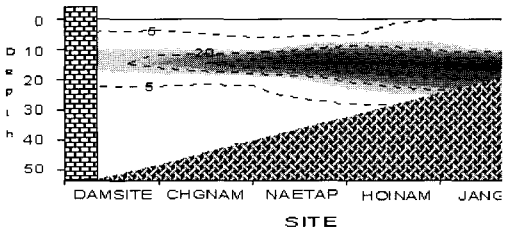

Fig. 2 Flow of turbid water after a rainfall event - Débit d'eau bourbeuse après une chute de précipitations.

Table 1 *Variation of water quality in reservoir by depth after rainfall* - Variation de la qualité de l'eau dans la retenue selon la profondeur après précipitations

Classifi -cation	SS (mg/l)			COD (mg/l)			T-N (mg/l)			T-P (mg/l)		
	U	M	L	U	M	L	U	M	L	U	M	L
Before Inflow	1.2	0.6	0.2	2.0	1.9	2.0	1.24	1.24	1.24	0.002	0.002	0.002
During Inflow	3.0	73.3	58.5	2.5	4.9	4.3	1.39	1.49	1.64	0.010	0.090	0.072
After Inflow	0.6	20.8	38.0	2.2	3.4	3.5	1.49	1.45	1.45	0.009	0.050	0.068
After Inflow	1.0	8.0	11.4	2.2	2.6	2.8	1.21	1.43	1.24	0.016	0.034	0.051

U : Upper Layer, M : Middle Layer, L : Lower Layer

Table 2 Status of fish farms in Daecheong reservoir - Pisciculture dans la retenue de Daecheong

Year	Number	Area (m^2)		Total Area (m^2)	Remarks
		Fishfarm	Subsidiary		
1994	17	192,750	27,269	220,019	
1995	15	186,750	24,892	211,642	
1996	15	186,750	24,892	211,642	
1997	5	76,320	10,487	86,807	
1998	0	0	0	0	

removed up to 1998. However, the sediments from them still releases nutrient and they contaminate water.

In natural circulation process of reservoir, organic matters are accumulated and the quantity of them depends largely upon the degree of trophic in reservoir. As the degree of eutrophication gets higher, concentration of dissolved oxygen in deeper part becomes lower and this makes the dissolution of sediments slow. Capacity of reservoir also decreases whereas eutrophication becomes faster because the release of nutrient increases.

3.2. Inveatigation of sediment depth

Daechung dam, which was launched in 1975 and completed in 1980, has been a major water resource in Choongchung area over the last 20 years. In this research, piston coring was adopted to analyze the sediments at 9 locations where we expected there would be thick sedimentation and the results are shown in table 3.

The sediment depth at Naetap 1 location was 1.2 m. According to the result of seismic investigation, the bed of reservoir was found to be relatively plain and the west slope was steeper than the east slope. The length of

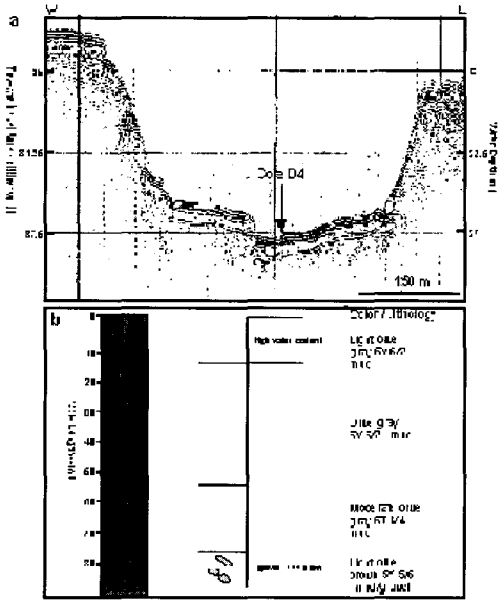

Fig. 3 (a) Naetap 1 coring site photograph Site de "coring" de Naetap 1
(b) X-ray Radiographie

Table 3 Coring position and depth of sediment "Coring position" et profondeur des alluvions.

Name	Location		Water depth(m)	Sediment depth (cm)	Before Dam Const. (cm)	After Dam Const. (cm)
	Latitude	Longitude				
Mueui-1	36° 30′ 20″	127° 30′ 15″	20.3	66	16	50
Mueui-2	36° 29′ 26″	127° 29′ 21″	30.4	62	9	53
Mueui-3	36° 28′ 58″	127° 29′ 21″	38.5	35	0	35
Naetop-1	36° 26′ 17″	127° 34′ 38″	27.1	85	7	78
Naetop-2	36° 25′ 34″	127° 33′ 57″	25.3	85	25	60
Hoenam-1	36° 25′ 38″	127° 33′ 30″	27.5	100	10	90
Hoenam-2	36° 25′ 30″	127° 33′ 24″	34.8	68	13	55
Hoenam-3	36° 26′ 08″	127° 30′ 42″	38.4	102	39	63
Hoenam-4	36° 24′ 30″	127° 30′ 06″	29.0	62	20	42
AVERAGE				73.9	15.5	58.4

sample core around this area was 85 cm and depth of water was 27 m (fig. 4). The sample core was filled with parallel layers at the range of 0~18 cm. The Fig. 3

structure between 18 cm and 30 cm was homogeneous and at the range of 30~40 cm, accumulation layer which contains sand was found. Below 78 cm range, gravels were found whose maximum diameter was 4.5 cm. The color of sample core changes from light olive brown to olive gray as it moves from the lower part to the upper part (fig. 4).

At Naetap 1 location, silt sediments were observed above 78 cm point and sediments with gravels were observed below this point. The latter is considered to be the soil of weathered rock which have been there before the dam construction. By this fact, it is inferred that 78 cm of sediments have been formed since the dam construction.

3.3. RELEASE CHARACTERISTIC OF SEDIMENTS

Sediment pass through biological, physical and chemical processes like dissolution, diffusion, re-floating and disturbed by fish. Afterwards, they are released to the water and have influence on water quality and ecosystem. In reservoirs, water temperature, pH, dissolved oxygen concentration, and the concentration difference between water layer and sediment affect the release characteristic of nutrient. Among them, the changes of dissolved oxygen concentration varies the condition of oxidization

Table 4 Release rate of TN at Daecheong reservoir - Taux de TN déversé à la retenue de Daecheong

Year	Location	Release rate (mg/m2 · day)	Condition	
			DO	Temp.
2001	Hoenam	23.20	Anaerobic	25 °C
	Naetap	17.63		
	Hoenam	3.40	Anaerobic	20 °C
	Naetap	4.08		
	Hoenam	Not Detected	Anaerobic	10 °C
	Naetap	Not Detected		
1999	*Janggegyo*	27.05	Anaerobic	25 °C
	Daejeongri	5.06		
	Hoenam	16.52 ~ 41.97		
	Naetap	30.78		
	Dam	6.20		
		Not Detected	Aerobic	25 °C
1998	Hoenam	62.14~84.72	Anaerobic	25 °C
		Not Detected	Aerobic	25 °C
1997	Daejeongri	124.1	Anaerobic	Room Temp.
	Hoenam	191.4		
	Naetap	196.8		
	Dam	209.2		

- deoxidization process and so, it has an important influence on the release characteristics.

The experimental system used raw water taken at the site and filled for the sediments not to float in the devices. Rubber plates and acryl plates were used to cover the reactor tightly so that samples were not exposed to air. Light was also completely shut to prevent oxygen from being formed due to the photosynthesis of algae in the reactor. The water at target site was anaerobic and its depth was comparably deep. To make a similar condition for the experiment, N_2 gas was used to generate dissolved oxygen in water so that anaerobic condition was maintained. To keep the temperature of reactor, the reactor was placed in a water tank designed to keep a constant temperature.

The concentration of dissolved oxygen was comparably high at first, but it went down to below 1 mg/l two days after nitrogen gas was supplied. After that, an anaerobic condition which is below 0.5 mg/l was maintained. The pH value remained in a comparably constant range during the experiment.

In reservoirs, nitrogen and phosphorus are considered as major causes of eutrophication. In this study. the changes of nutrient concentration of effluent in the release experiment devices was analyzed to calculate the release amount of total

Table 5 Release rate of TP at Daecheong reservoir Taux de TP à la retenue de Daecheong

Year	Location	Release rate ($mg/m^2 \cdot day$)	Condition	
			DO	Temp.
2001	Hoenam	6.93	Anaerobic	25 °C
	Naetap	6.60		
	Hoenam	3.57	Anaerobic	20 °C
	Naetap	3.55		
	Hoenam	0.003	Anaerobic	10 °C
	Naetap	Not Detected		
1999	Janggegyo	4.12	Anaerobic	25 °C
	Daejeongri	5.51		
	Hoenam	4.52 ~ 7.86		
	Naetap	6.56		
	Dam	3.38		
	Chungju (Intake Tower)	3.54		
		0.0 ~ 0.807	Aerobic	25 °C
1998	Hoenam	13.02 ~ 14.38	Anaerobic	25 °C
		0.052 ~ 0.065	Aerobic	25 °C
1997	Daejeongri	5.52	Anaerobic	Room Temp.
	Hoenam	9.37		
	Naetap	5.54		
	Dam	7.72		

nitrogen, total phosphorus and dissolved phosphorus. Since the release experiment result owing to the phosphorus supplied by human being's activities rather than the nitrogen from water in nature are published more frequently, the result of this study is compared to those of foreign studies with respect to the case of phosphorus. Table 4 shows the release amount of TN at various locations in Daechung reservoir. According to the result of release experiments performed for Janggye-bridge, Daejung-ri, Hoenam, Naetap and the place near Dam in 1997 and 1999, Hoenam's result was the highest among them where lots of fish farms were located in the past. Based upon this result, the experiment of 2001 was focused on the release amount of Hoenam and Naetap considering water temperature changes and it was observed that release did not occur below 10 °C.

Water temperature in reservoirs varies as season changes but it also varies according to the depth of reservoirs itself. In Korean reservoirs, the temperature below 30 m in depth remains below 10 °C and dissolved oxygen remains in an anaerobic condition most of the time. Therefore, the experimental condition of this study was set similar to the conditions described above. The release amount of Hoenam and Naetap at 25 °C were 23.20 mg/m^2 · day and 17.63 mg/m^2 · day, respectively. At 20 °C, the observed value at the two locations were 3.40 mg/m^2 · day and 4.08 mg/m^2 · day.

At Hoenam location, total release amount of

Table 6 Release rate of nutrient from sediment Taux de nutriments des sédiments

Name	Condition (Temp. : °C)	Release rate (mg/m^2 · day)		
		T-P(PO_4-P)	Inorganic N	Others
Muddy River	Aerobic(24~30)	(AVE. 9.4)	NH_3-N;360	-
	Anaerobic (24~30)	(31~96)	NH_3-N;360	-
Lake Warner	Aerobic (24~30)	AVE. (1.2)	NH_3-N;120	-
	Anaerobic (24~30)	(19~26)	NH_3-N;120	-
Lake Baldeggerse (in situ)	Anaerobic	(AVE. 9~10)	-	-
Shagawa Lake	Simulate	4.3 4.3	8.6	-
Southern Lake Biwa	Aerobic (20) Anaerobic (20)	1.4~3.7(0.4~1.4) 16~41(10~25)	NH_3-N;2~4 NO_3-N;2~15 NH_3-N;45~65 NO_3-N;15~45	Kjeldahl-N ;40~70 Kjeldahl-N;106~145
Northern Lake Biwa	Anaerobic	(11.5)	-	-
Lake Suwa	Aerobic (17.1~22.2)	0~6.3	104~238	-
	Anaerobic(17.1~22.2)	2.3~36.6	19~199	-
Lake Deganuma	Upstream	97	-	Kjeldahl-N ; 292
	downstream	11	-	Kjeldahl-N ; 72
Cannonsville Lake (U.S.A)	Anaerobic	12.9±2.2	-	-
Trummen Lake (Sweden)	Anaerobic	1.4~4.4	-	-

phosphorus at 25 °C was 9.37 mg/m^2 · day, 13.02~14.38 mg/m^2 · day, 4.52~7.86 mg/m2 · day and 6.93 mg/m^2 · day in 1997, 1998, 1999 and 2001, respectively (table 5). Even though long term monitoring is required to be precise, the release amount at this location was observed to be decreasing gradually whereas the results at Naetap showed little change. The release amount in an anaerobic condition with respect to the change of water temperature at Hoenam and Naetap in 2001 decreased as the water temperature went down and at 10 °C, no release was observed.

The release amounts of this study found to be less than those of foreign cases. In Japanese reservoirs, the release amounts at an anaerobic condition were observed as follows: 16~41 mg/m^2 · day (20 °C), 2.3~36.6 mg/m^2 · day (17.1~22.2 °C), 97 mg/m^2 · day and 11 mg/m^2 · day in southern Lake Biwa, Lake Suwa, Lake Deganuma upstream and downstream, respectively. That of Cannonsville Lake in the U.S. was 12.9±2.2 mg/m^2 · day which is also higher than this study's result except the results of Shagawa Lake and Trummen Lake whose observed value were 4.3 mg/m^2 · day and 1.4~4.4 mg/m^2 · day, respectively.

The release amounts of PO_4-P at Hoenam, where lots of artificially formed sediments were

Table 7 Release rate of PO_4-P at Daecheong reservoir Taux de PO_4-P dans la retenue de Daecheong

Year	Location	Release rate (mg/m^2 · day)	Condition	
			DO	Temp.
2001	Hoenam	6.074	Anaerobic	25 °C
	Naetap	5.223		
	Hoenam	5.234	Anaerobic	20 °C
	Naetap	4.773		
	Hoenam	0.002	Anaerobic	10 °C
	Naetap	Not Detected		
1999	Janggegyo	0.612	Anaerobic	25 °C
	Daejeongri	0.311		
	Hoenam	1.020 ~ 3.550		
	Naetap	2.769		
	Dam	0.463		
	Chungju (Intake Tower)	2.377		
		Not Detected	Aerobic	25 °C
1998	Hoenam	2.056	Anaerobic	25 °C
		Not Detected	Aerobic	25 °C
1997	Daejeongri	6.804	Anaerobic	Normal Temp.
	Hoenam	6.768		
	Naetap	4.627		
	Dam	3.248		

found, were 6.768 mg/m^2 · day, 2.056 mg/m^2 · day, 1.020~3.550 mg/m^2 · day in 1997, 1998 and 1999, respectively. These values seemed to decrease gradually, but in 2001, the observed value was 6.074 mg/m^2 · day at 25 °C (table 7). Since the release rate varies according to the gathered samples, long term experiments for various samples are required to get more precise results. All the observed values above were less than the values of Muddy river, Lake Warner, Lake Baldeggerse and Lake Biwa shown in table 6. In the release experiment with respect to the change of water temperature performed in 2001, almost no release was observed below 10 °C like other water quality items. In deep reservoirs like Daechung reservoir, depth is over 30 m from near the dam to the middle part of the reservoir and water temperature remains below 10 °C, it is estimated that no release is occurred in this area. At the area where depth is below 30 m, the release rate increases rapidly when water temperature rises in summer.

4. CONCLUSION

The following are conclusions of this study about the distribution of organic sediments and the release characteristic of Daecheong reservoir.

1) The particle size in turbid water flows near to the dam varies depending upon the characteristic of the rainfall event. However, particles less than 10 ㎛ in size found to be around 50 % in this study. The values of SS and TP observed to increase up to 73.3 mg/l and 0.09 mg/l, respectively.
2) Piston coring was performed to analyze the sediments at 9 locations where we expected there would be thick sedimentation. As results, the maximum value was 90 cm at Hoename-1 location, the minimum value was 35 cm at Muneui-3 location and the average value of 9 locations was 58.4 cm.
3) The release rate of nutrient from sediments was not higher than that of foreign cases and it appeared to be decreasing as the number of fish farms are diminishing. The release rate of TN at Hoenam, where a lot of fish farms were located, was 62.14~84.72 mg/m^2 · day in 1998 and reduced greatly to 23.20 mg/m^2 · day in 2001. In case of TP, it was 13.02~14.38 mg/m^2 · day in 1998 and reduced to 6.93 mg/m^2 · day in 2001.
4) The result of release experiment with respect to the change of temperature shows that the release of TN did not occur at 10 ° C. The release rate of TP and PO4-P at this temperature were 0.003 mg/m2 · day and 0.002 mg/m2 · day, respectively, which belong to very low range.

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SUMMARY

The inflow into a multi-purpose dam reservoir contains many suspended solids from the upper stream during the rainy season. Concentrations of SS increased to 73.3 mg/l and the TP measurement increased to 0.09 mg/l during the rainy season in 1999. It was discovered that particles less than 10 ㎛ in size composed about 50 % of the total amount. Some of these particles reduce the reservoir capacity and have an impact on water. In this study, the sediment depth at Daecheong multi-purpose dam was examined. Piston coring was performed at 9 locations. At Hoenam 1 out of 9 locations examined showed maximum depth, which was 90 cm and at Muneui 3 showed the minimum depth, which was 35 cm. At Hoenam, the release rate of TN was found to be 62.14~84.72 mg/m^2 · day in 1998. However, it was found to considerably reduced to 23.20 mg/m^2 · day in 2001. The release rate of TP was measured at 13.02~14.38 mg/m^2 · day at 1998, and it was reduced to 6.93 mg/m^2 · day in 2001.

Résumé

L'afflux dans une retenue de barrage multi-fonction contient de nombreux solides en suspension venant de l'amont pendant la saison des pluies. Les concentrations de SS ont augmenté jusqu'à 73. 3 mg/l et la quantité mesurée de TP a augmenté jusqu'à 0.09mg/l pendant la saison des pluies.On a decouvert que les particules de taille inferieure à 10㎛ composent environ 50% de la quantité totale. Certaines de ces particules réduisent la réserve totale et ont un impact sur l'eau. Dans cette etude la hauteur des alluvions du barrage multifonction de Daecheong a été examinée. Un "piston coring" a été réalisé à 9 endroits. A Hoenam 1 des 9 éndroits examinés montre une epaisseur maximale, qui était de 35cm. A Hoenam, le taux de TN relaché constaté était de 62.14 à 84.72 mg/m2 par jour en 2001. Le taux de TP relaché mesuré s'élevait de 13.02 à 14.38 mg/m2 par jour en 1998 et a été réduit à 6.93 mg/m2 par jour en 2001.