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Distribution of Nutrients in Dae-Cheong Reservoir Sediment

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This paper was performed to estimate interrelations between humus level of sediments and nutrient release from sediments in Dae-cheong reservoir. For investigations, sediments were sampled in June and October, in 1997 at fish farms, embayment, and the main stream of Dae-cheong reservoir. Items for investigation are as follows; water content, weight loss on ignition(IG), porosities of sediments, contents of element such as hydrogen, nitrogen, carbon, and nutrient release rates. Water contents and porosities were measured to conjecture the physical trait and grain size trait. Weight loss on ignition was measured to determine the contents of organic substance. For determination of the humus level of sediments, carbon and nitrogen contents were measured by elemental analyzer. As a result of elemental analysis, C/N ratio was determined in the range of 3.0~13.1. From the elemental analysis, humus level of Dae-cheong reservoir sediment was estimated from mesohumic state to oligotrophic state. For the determination of nutrient release rate, PO_4-P and NH_4-N concentrations of interstitial water and overlying water were measured. By using the concentration difference between interstitial water and overlying water and using the Fick's diffusion law, the release rates of phosphorus and nitrogen from the sediment samples were calculated. Release rates of nutrients which directly influence to the water quality were 0.05~8.63mgP/m^{2}day and 4.99~36.56mgN/m^{2}day. It was found that release rate was measured higher in the 1st sampling period than in the 2nd sampling period. For the determination of phosphorus content in sediment, TPs were measured in 807~1542μg/g in the 1st samling period and 677~5238μg/g in the 2nd samling period. Phosphorus release rate and phosphorus content were not interrelated each other.

Key words : Reservoir sediment, Humus level, Interstitial water, Overlying water, Release rate, Nitrogen release, Phosphorus release.

1. Introduction

Trophic types of lakes depend on the relationship between the supply of organic matter from autotrophic and allotrophic sources. As important as trophic level of lake, sediments located in the lowest bed of lakes play an important role in deciding trophic state of lake. Sediment types, like lake types, can be classified according to several principles and many sediments parameters. At the outset, it should be emphasized that some confusion presently exits concerning classification and nomenclature on lake sediments. In terrestrial sedimentologies, sediment classification can be based on numerous sediment characteristics, such as color, structure, grain size, organic content, algal content, benthic community. And the study area of sediments are divided in several groups;

on the organic parts of sediment, on the physics and chemistry, and on the mineralogy. An elaborate and useful classification is introduced by Hansen(Hansen, 1959(*a*)). He differentiated by means of mineral grain size and dominant plankton groups. But Classifications by Hansen were confused easily by non-experts. Nowadays, many geologists are using systematic classification organized by many experimental components ; Weight loss on ignition, carbon contents, nitrogen conents, and phosphorus contents, silicon and carbonate contents. Humic level of sediments were guessed using Hansen's method(Hansen, 1959*b*). Hansen concluded in his published paper that if the contents of organic carbon less than 50% and C/N ratio less than 10 the humus is neutral, and if the contents of organic carbon is higher than 50% and the C/N ratio is higher than 10, the humus is acid. Humus is a brown, grey or dark substance whose chemical composition is still largely unknown. But it can be subdivided into two main types, acid humus and neutral humus. In colloid-chemical point of view, acid humus is presumed to be an unsaturated sol with negatively charged particles, and neutral humus is thought to be a gel where anions are adsorbed to the surface of the humus particles.

Like in many foreign countries, there are many man-made dam in our country. In 1960s~1970s, for the development of economy, many multipurpose dams were constructed. After constructing, by large amounts of domestic swage and industrial effluents water pollutions were major issues for national aspect. And, many artificial lakes are being eutrophicated due to the supply of organic matter produced allochthonous and autochthous sources. Many researchers were studying on how to control allochthonous nutrient sources for the past several decades. Recently, however, controlling the release of nutrients from sediments is becoming an increasing concern since the nutrient concentration of sediment in stagnent area can be several or tenth of thousands times bigger than that of lake water due to the accumulation of the nutrients for a long period. In Dae-cheong reservoir, there were many fish farms before 1996. In fish farms, many fishers used large amounts of fish feed for fish rearing. Fish feed which was not uptaken by fish and the excrements from fish have also been accumulated on the reservoir bottom. In this work, by using Hansen's theory we could deduce the humus level of Dae-Cheong reservoir sediment. For the determination of humus level, we analyzed the contents of elements like; hydrogen, carbon, nitrogen and sulfur. And comparing the carbon and nitrogen contents, we could indirectly estimate the humus level of sediment. And to make clear the relations of sediment and water quality, we colud not ignore the effects of nutrient release from sediments in the bottom of reservoirs. Therefore, we made an effort to calculate the nutrient release rates using mathematical model. Mathematical model applied in this work, we used the Fick's diffusion law. Mathematical model used for calculating the NH_3-N and PO_4-P gradient between the overling water and the interstitial water in the uppermost layer of sediment was well applied. The method for estimating flux from lake sediments are classified into two steps. In the first step, the concentration difference of nutrient is estimated from the measurement of the concentration of overlying waters and interstitial waters. In the second step, flux is calculated from Fick's law, i.e., flux is proportional to the gradient of nutrient concentration at the sediment-water interfaces. And, to compare the phosphorus release rate and phosphorus contents in sediment, phosphorus contents in sediment were determined. Total phosphorus contents was determined by the ignition method of Anderson(Anderson, 1975).

Table 1. Hydrological characteristics of Dae-Cheong reservoir.

Parameter	Dae-Cheong reservoir
Basin Area	4,134 km^2
Watershed Area	72.8 km^2
Watershed Length	86 km
Maxmum Volume	1,490 × $10^6 m^3$
Effective Volume	790 × $10^6 m^3$
Mean Inflow Volume	2,677.4 × $10^6 m^3$

2. Experimental Method

Sampling periods were chosen to compare the release rate difference between in summer which the water temperature is high and in autumn which the water temperature is low. The First samplings were done June 16 to June 20 and second sampings were done October 15 to October 20 in 1997. And, sampling sites were selected for comparing the regional characteristics of Dae-Cheong reservoir. So we could select 4 sampling sites; at fish farms in Hoenam, embayment in Chudong and Chusori, and the main stream in Munee. Instrument used for sampling was Core Sampler made by Wild Co. in U.S. of which column dimension is 4.8 cm(i.d.) x 50 cm(L.). Sample columns were carried to a laboratory and the experiments were done immediately. In case the measurements were difficult to proceed instantly, the samples were frozen. The sediment sampling sites are shown in Figure 1.

2.1. Water Contents and Ignition Loss

A column of sample was cut by 0~2 cm and the top layer was centrifuged to take out interstitial water for 30 min at 3000 rpm. The samples which centrifuged were dried at 105~110℃ until the weight loss was constant. Water contents were calculated from the weight loss after cooling the dried sediment to the room temperature in desiccator. And, loss on ignition was determined by measuring the weight loss after igniting the dried sediment (ca. 10 g) at 550℃ for 1 hour in electric furnace. And, porosities of sediment were calculated from the pore volume divided by the total volume of the sediment. The pore volumes were estimated by using the water contents. And the total volume of the sediment was the sum of the water volume determined from the water content and the volume of dried sediment.

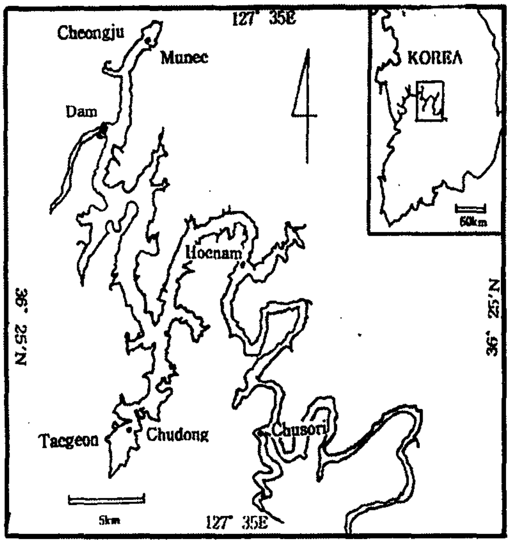

Fig. 1. The sediment sampling sites in Dae-Cheong reservoir.

2.2. Determination of Carbon and Nitrogen Contents

Carbon and nitrogen contents of the dried sediments were measured using an elemental analyser. The major principle of an elemental analyzer is the dynamic combution method like; the sample coated in tin capsule and placed in autosampler is dropped into a quartz tube kept at 1000℃ and with helium continuously flowing there through. At start up, carrier gas is enriched with a known quantity of oxygen and the sample is dropped into the tube a few moments before oxygen arrives, thus a violent exothermic reaction occurs. The gas mixture developed by oxidation passes on the catalytic layer present in the quartz tube. Gas passed catalytic layer is transferred into the gas chromatic column and then each single components are separated

2.3. Nutrients Release Rates

To determine the concentrations of nutrients in interstitial water, columns of sediment samples were cut by 0~2 cm and top layers of each columns were centrifuged to gain interstitial water at 3000 rpm for 30 minutes. The interstitial water obtained was filtered through 0.5 μm membrane filter and was diluted to an adequate concentration for the analysis. NH_4-N, PO_4-P concentrations were determined by phenate and ascorbic acid reduction methods, respectively. And, nutrients release rates from the sediment were calculated using the method based upon Fick's diffusion law(Hosomi, 1981) which is

$$R = \Phi \cdot D_t(C_i - C_w)/\Delta L \quad (1)$$

where

Φ : porosity of the sediment

D_t : diffusion coefficient (m^2/day) of a nutrient at t℃

C_i : concentration (mg/m^3) of a nutrient in the interstitial water of the surface sediment

C_w : concentration (mg/m^3) of a nutrient in the overlying water

ΔL : difference of depth of the sediment sample (m).

As can be seen in the above equation, the release rate is proportional to the diffusion coefficient of a nutrient which depends on the kinds of nutrients, the porosity of the sediment, and the physical or biological turbulences on the sediment. The diffusion coefficients determined by many researchers are used to calculate the effective dispersion coefficient.

$$D = D_0 \cdot \Phi^2 \quad (2)$$

D : effective dispersion coefficient (m^2/d)

D_0 : molecular diffusion coefficient(m^2/d) when Φ=1

The molecular diffusion coefficients of NH_4-N and PO_4-P used in this study are 8.5 x $10^{-5}m^2$/day and 5.3 x $10^{-5}m^2$/day, respectively. Diffusion coefficient is corrected as in the equation (3) since it depends on temperature.

$$D_t = D \cdot (1 + a \cdot t) \quad (3)$$

D_t : diffusion coefficient(m^2/day) at t℃

a : temperature correction coefficient (1/℃)

t : temperature (℃)

In this study, 0.04 for the value of 'a' was used for NH_4-N and PO_4-P.

2.4. Determination of Phosphorus Contents

Total phosphorus content,(TP) in sediment was determined by the ignition method of Anderson (Wildung 1973; Anderson, 1975). Determination of total phosphorus in soil, sediment or biogenic matter involves a preliminary digestion to convert the phosphorus into orthophosphate. Comparative studies of different methods for determination of total phosphorus in sediment have been made by Sommers(Sommers, 1970; Nordforsk, 1974). Digestion with pherchloric acid is the most common and generally accepted procedure. Determination of total phosphorus in lake sediment by ignition of sample in a muffle furnace at 550℃, boiling of the residue from ignition in 1N HCl. and subsequent dstermination of orthophosphate gave approximately the same values as the pherchloric acid digestion.

Dried sediment or plant material was ignited in a muffle furnace in a porcelain(550℃ for 1h). After cooling, the residue was washed into a 100ml erlenmeyer flask with 25ml 1N HCl and bolied for 30min on a hot plate. And then, the sample was diluted to 50ml in a volumetric flask, and orthophosphate was determined. And, the determination of total inorganic phophorus(IP), it was extracted by 1N HCl for 16h at room temperature and then the concentration of phosphorus in extract was analyzed. And total organic phosphorus(OP) was determined by substracting the value of IP from that of TP(Aspila et al, 1976). For the determination of fractionate of IP in this study, we used the method proposed by Chang and Jackson(1950). In this method, three fractions of phosphorus extracted by NH_4Cl, NH_4F, NaOH and H_2SO_4 were defined as aluminum bound phophorus (Al-P), iron-bound phosphorus(Fe-P), calcium-bound phosphorus(Ca-P), respectively.

3. Results and Discussion

3.1. General Features of Sediment

The depth of water at the sampling sites could be an important factor which affects water temperature and the stratification phenomenon. And it thereby gives an effect on the nutrient release from sediments. Depth of water, depth of sediment at sampling sites, water contents, and porosities of surface sediments were measured and are shown in Table 2. The depth of water at the sampling sites were in the range of 17~27m in the 1st period and 12~24 m in the 2nd sampling period. And, the depths of sediment were 11.0~27.0 cm in the 1st samples and 12~24 cm in the 2nd samples. The water contents were 41.0~70.0% and the porosities were in the range of 62.1~84.6%. By these measurements it can be guessed the fact that the sediment of Dae-Cheong lake is composed of silt or clay.

3.2. Loss on Ignition

Generally, loss on ignitions were used to estimate organic contents of soil and sediment. In this study, we calculated the loss on ignitions by using the difference of weight after digestions. Loss on ignitions was measured in 2.4~14.5% in the 1st sampling period and 9.2~16.2% in the 2nd sampling period as shown in Table 3. And, it is shown that the weight loss on ignition increases as the depth of sediment increases. And, IG values of the 2nd samples were measured somewhat higher than the 1st samples and so it can be concluded that the sediment of Dae-Cheong reservoir was formed by the precipitation of organic matter. And also relatively high IG values were found from the sediment samples collected at fish farm areas like Hoenam and estuaries like Chusori.

3.3. Determination of Trophic State

Organic sediments in reservoirs and lakes are like the uppermost horizon insoils, a mixture of minerogenic matter and remains of plants and animals. Humus is a brown, grey or black substance whose chemical composition is still largely unknown. From a chemical point of view, acid humus is presumed to be an unsaturated sol with negatively charged particles, and neutral humus is thought to be a gel where anions are

Table 2. General items of sediment samples.

Sites	Item	Water depth(m)		Sediments Depth(cm)		Water Content(%)		Porosity (%)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Munee	Site 1	20	19	11	15	59	51	79.0	76.5
	Site 2	19	17	14	18	62	59	78.0	76.0
	Site 3	18	18	16	16	63	68	77.0	77.0
	Site 4	19	20	17	17	61	70	79.0	75.0
Chudong	Site 1	16	15	14	12	56	45	79.3	85.9
	Site 2	14	12	15	16	59	50	78.5	80.0
	Site 3	13	13	16	15	60	52	77.3	75.3
	Site 4	15	14	18	22	62	53	77.7	77.1
Hoenam	Site 1	28	25	14	13	54	45	76.7	69.5
	Site 2	25	24	18	22	59	48	76.4	68.4
	Site 3	26	23	20	24	58	49	75.9	65.3
	Site 4	27	24	24	20	57	47	74.8	62.1
Chusori	Site 1	23	21	22	20	51	41	84.6	64.6
	Site 2	22	20	26	20	63	50	83.2	63.5
	Site 3	24	19	25	19	62	64	80.4	64.2
	Site 4	20	18	27	21	68	66	79.0	65.1

adsorbed to the surface of the humus particles. In sedimentologies, a distinction between two types of humus is very important. This can be expressed as the content of organic carbon and the carbon and nitrogen ratio. About the humus level of sediments, Hansen said in his paper published in 1959 that if the organic content of organic carbon is less than 50 percent and the the C/N ratio less than 10 the humus is neutral, and if the contents of organic carbon is higher than 50 percent and C/N ratio is higher than 10, the humus is acid. In this paper, contents of organic carbon and organic nitrogen were presumed to be well fitted content of elemental contents by elemental analysis. Because elemental analysis was conducted in the reactor tube(ca. 1800℃), all organic substance would be combustioned.

In addition to Hansen's theory, the correlations between the nutrients release from sediments and trophic state of sediments were conducted by Håkanson. According to Håkanson(Håkanson, 1984) IG to TKN content ratio can be used as a rough measure of humus level of sediments. Sediments with IG/TKN ratio larger than 25, between 20 and 25, and smaller than 20 are considered to be polyhumic, mesohumic, and oligohumic, respectively. But, determining the humus level by IG/TKN may not be proper in the case of the lake sediments in Korea of which IG values are mostly lower than 10%. And Håkanson clearly states that the correlation between the TKNs and the loss on ignition is generally good only when the IG is larger than 10%. In many lakes in our country, IGs were measured less than 10%, so we could guess that C/N ratios were well fitted than IG/TKN ratios. In this study, for determing the humus level of sediments, C/N ratio calculated using elemental contents is considered to be more reliable than that done based on IG/TKN. The C/N ratios for sediments determined using elemental analyser were shown in Table 3. The C/N ratios were higher in most areas in 1st sampling period than the 2nd sampling period. Therefore, in the 1st sampling period, it could be concluded that the decomposition rate of organic materials is faster than in the 2nd sampling period. And in the 2nd sampling period, C/N ratios of all areas were measured lower than 10. Compared with C/N ratios in sampling periods, it could be predicted that the decomposition rate of organic materials would be faster in the 1st sampling period than the 2nd sampling period. As a result of elemetal analysis, trophic states of sediments in Dae-Cheong reservoir were estimated in oligohumic and mesohumic states like shown in Figure 2.

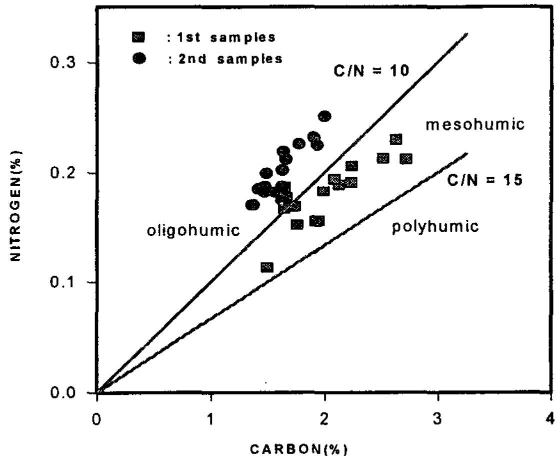

Fig. 2. Nitrogen contents versus carbon contents in sediment samples from Dae-Cheong reservior.

Table 3. Weight loss on ignitions and elemental content of sediment.

Sites \ Items		IG(%)		Hydrogen(%)		Carbon(%)		Nitrogen(%)		C/N	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Munee	Site 1	2.4	10.1	0.919	0.771	1.756	1.621	0.152	0.175	11.5	9.2
	Site 2	14.5	12.2	1.140	0.869	2.119	2.002	0.189	0.251	11.2	7.9
	Site 3	12.1	12.0	1.097	0.720	1.945	1.487	0.156	0.199	12.4	7.4
	Site 4	11.8	12.4	1.238	0.877	2.080	1.636	0.194	0.219	10.7	7.4
Chudong	Site 1	9.6	11.6	1.001	0.582	1.656	1.415	0.177	0.185	9.3	7.6
	Site 2	10.5	9.2	0.753	0.675	1.491	1.469	0.113	0.182	13.1	8.0
	Site 3	10.8	13.0	1.203	0.698	2.229	1.374	0.191	0.170	11.6	8.0
	Site 4	10.8	13.1	1.236	0.727	2.235	1.361	0.206	0.170	10.8	8.0
Hoenam	Site 1	10.8	9.6	1.207	0.725	1.644	1.935	0.187	0.225	8.7	8.6
	Site 2	10.3	11.2	1.224	0.715	1.644	1.629	0.167	0.202	9.8	8.0
	Site 3	10.3	10.8	1.043	0.740	1.736	1.657	0.169	0.212	10.2	7.8
	Site 4	11.1	16.2	1.340	0.749	1.921	1.774	0.155	0.226	10.8	8.5
Chusori	Site 1	8.9	10.7	1.043	0.517	1.984	1.472	0.183	0.187	10.8	7.8
	Site 2	8.9	12.3	1.069	0.760	2.511	0.562	0.213	0.182	11.7	3.0
	Site 3	9.8	12.5	1.125	0.855	2.629	1.908	0.230	0.232	11.4	8.2
	Site 4	9.2	12.3	1.032	0.849	2.716	1.623	0.212	0.187	12.8	8.6

3.4. Release Rate of Nutrients

The concentrations of PO_4-P and NH_4-N in the interstitial and in the overlying water were measured to determine their release rates and are listed in Table 4 and Table 5. Generally, PO_4-P and NH_4-N concentrations in the interstitial water were much higher than those in the overlying water. The concentrations of PO_4-P and NH_4-N in the interstitial and in the overlying water were determined in the range of 0.02 mg/L~1.531 mg/L and 0.005 mg/L~4.471 mg/L. As shown in Table 5, in most areas except Munee, the NH_4-N release rate were measured higher in 1st samples than 2nd samples, which indicates that NH_4-N was released from sediments as the degradation process progressed during water temperature rising season. Compared with results, it was found that NH_4-N and PO_4-P concentrations in the interstitial water are relatively high in fish farms like as in the Hoenam area and in the embayment as in the Chusori area. Especially, the chusori area in first sampling period, NH_4-N and PO_4-P concentrations in the interstitial water were measured most highly. As shown in the C/N ratio of this period, the C/N ratio was measured most highly. So it can be concluded that there is interrelationship between nutrient concentration and C/N ratio. About the relations of C/N ratios and nutrient release rate, Nikaido suggested in his published paper in 1978 that the sediment with lower C/N ratios contain a large amount of easily decomposable organic matter than with the sediment with higher C/N ratios. Comparing the results of C/N ratios between the 1st sampling periods and the 2nd sampling periods, C/N ratios of the 2nd samples after flooding season were determined higher than that of the 1st samples. This means that much organic matter were included in reservoir during the flooding season. And Koyama said in his paper in 1966 that the higher the C/N ratio of the sediment, the mineralization rate of organic substance was faster than lower C/N ratios. As shown in Table 3, C/N ratios of the 1st samples were determined somewhat higher than the 2nd samples. This means that the decomposable rate of organic substances would be faster in the 1st sampling period than in the 2nd sampling period. Therefore, release rates of nutrient could be determined higher in the 1st sampling period than the 2nd sampling period. So the humic state would be changed from the mesohumic state in the 1st sampling period to the oligohumic state in the 2nd sampling period.

The anaerobic condition of the lake bottom is mainly due to the accumulation of organic matter originating from fish farming and of the incoming

Table 4. Concentrations of the dissolved nutrients in the interstitial and in the overlying water.

Sites	Items	PO_4-P (mg/L)		NH_4-N (mg/L)	
		1st	2nd	1st	2nd
Munee	overlying	0.020	0.011	0.336	0.162
	interstitial	0.205	0.190	1.004	1.885
Chudong	overlying	0.015	0.003	0.251	0.075
	interstitial	0.939	0.051	1.711	1.020
Hoenam	overlying	0.028	0.019	0.179	0.311
	interstitial	0.593	0.039	2.086	4.471
Chusori	overlying	0.046	0.005	0.695	0.165
	interstitial	1.531	0.092	4.617	3.091

materials during the flooding season. Generally, It was known that effective components of influencing the release rate are interstitial and overlying water concentration, porosity, temperature, benthic animal activities. And therefore, release rates of nutrients were determined by multiple relationships among these components. Hence, the release rates of nutrients are low in winter and autumn because of the low hyperlimnion temperature and the low degradation rate of organic materials. The internal loadings of phosphorus at the embayment area and fish farms could be important in judging from high DRP concentrations and the phosphorus release rates as can be seen in Table 5.

3.5. Phosphorus Content in Sediment

Sediment in the bottom of lake is known to play an important role in the nutrient release. Generally, in a lake restoration program, we cannot ignore the effect of the sediments on the phosphorus budget. If the restoration program has been completed, there were examples where water quality did not improve to the desired levels because of the phosphorus release from the sediment(Welch, 1977). Many studies have reported on the rate of phosphorus release from the sediment. These studies were conducted under defined environmental conditions, aerobic or anaerobic, using specific lake sediments(Fillos, 1975; Freedman, 1977; Okada, 1978). These results, however, differ greatly from case to case, even among sediment samples from the same lake, depending on the experimental conditions and or characteristics of sediment. The purpose of this section was to clarify the relationship between the amount of various fractions of phosphorus contained in the sediment. Phosphorus in the sediment was fractionated each bound forms before and after phosphorus release. Value ranges of TP were in 807~1542 μg/g in the 1st samples and 677~5238 μg/g in the 2nd samples. Overall, variations of phosphorus content in the 1st sample was more fluctuated than the 2nd sample. And, content at Hoenam and Chusori area was higher than any other places. Theoretically, it is very difficult to extract phosphorus by NH_4Cl solution. But, in this work some of fraction of NH_4Cl-P was extracted and its values were 0.564~2.20 μg/g and 0.169~3.323 μg/g in each sampling periods. Viewing the inorganic phosphorus, contents of Fe-P extracted by 0.1M NaOH solution were measured in highst values. In the case of Fe-P, Hosomi(1979) said in his paper that both the amount of aerobically released phosphorus and maximum growth yield of algae were proportional to Fe-P fraction in the sediment and the amount of released phosphorus was about 90% of the Fe-P fraction in the sediment. In our experiment, the fraction of Fe-P was measured in maximum values in inorganic phosphorus fractions. And

Table 5. Release rate of PO_4-P and NH_4-N.

Sites \ Item	Diff.coeff. of phosphorus ($\times 10^{-5} m^2$/day)		Release rate (mgP/m^2day)		Diff.coeff. of NH4-N ($\times 10^{-5} m^2$/day)		Release rate (mgN/m^2day)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Munnee	5.90	5.16	0.86	0.70	9.46	8.27	4.99	10.95
Chudong	6.22	6.57	4.56	0.26	9.98	1.05	11.57	8.56
Hoenam	6.01	4.27	2.60	0.05	9.64	6.84	36.56	10.96
Chusori	6.87	3.59	8.63	0.20	1.10	5.77	13.97	19.86

organic fractions were proportional to the TP content of sediments. And in comparison of phosphorus release rate and phosphorus content in sediment, it was found that release rate of phosphorus was not related in so much as phosphorus content in sediment. For example, in the Hoenam area of the 2nd sample period, phosphorus content of sediment was measured the largest values but the phosphorus release rate was not measured the highest values as much as we expected. This is because the nutrient release rate is affected by various conditions in the water body like as; DO, pH, benthic animal activity, water temperature, redox potential, movement of water body, etc.

4. Conclusions

1. The depths of sediment were 11.0~29.0 cm and water contents were in the range of 41~70%. The porosities were in the range of 64.6~84.6%, so we could guess that distribution of sediment particles would be silty and sandy.

2. IG values during the first and the second sampling periods were measured in the range of 9.6~10.7% in 1st sampling period and 2.4~10.9% in 2nd sampling period. Organic contents which were calculated by weight loss on ignition were measured in scope of 10% in most sampling sites.

3. Carbon to nitrogen content ratios for the 1st samples were 8.791~11.553, and C/N ratios of 2nd samples were measured lower than 10, in scope of 7.648~9.262 in most areas. It implies that the humus level of sediments would be changed from oligohumic to mesohumic state for an interval of three months between the

Table 6. Phosphorus content in sediment.

	Items	T-P(μg/g)		I-P(μg/g)								O-P(μg/g)	
				NH_4Cl-P		Al-P		Fe-P		Ca-P		TP-IP	
Sites		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Munee	Site 1	1193	1196	-	-	0.139	0.457	427	458	0.885	0.969	765	737
	Site 2	1222	787	-	0.211	0.028	0.371	428	458	1.542	0.642	793	329
	Site 3	1086	677	-	0.436	0.202	0.291	440	481	1.868	0.402	646	195
	Site 4	1280	1041	-	0.269	0.245	0.046	459	494	0.665	0.639	820	547
Chudong	Site 1	1056	772	2.20	0.275	0.471	1.260	463	360	12.055	0.478	593	411
	Site 2	807	805	-	-	0.949	0.420	328	373	1.347	0.733	478	161
	Site 3	1360	842	0.058	0.926	0.585	0.522	421	343	1.925	0.792	938	498
	Site 4	1260	880	0.257	0.319	5.176	0.371	431	400	2.150	0.889	828	480
Hoenam	Site 1	1431	5238	-	3.323	0.712	0.116	545	1079	0.804	1.891	886	4159
	Site 2	1511	2190	-	0.431	0.723	1.297	482	958	0.361	1.610	1028	1231
	Site 3	1382	2520	-	1.034	0.499	0.753	549	978	1.531	1.652	832	1541
	Site 4	1437	1951	1.120	0.430	1.076	0.125	569	818	0.870	1.039	867	1133
Chusori	Site 1	1396	939	0.609	0.295	0.694	0.207	630	367	1.034	1.543	766	571
	Site 2	1400	917	0.319	0.402	1.232	0.085	618	351	0.014	0.706	782	565
	Site 3	1542	987	1.048	1.076	0.217	0.788	582	496	2.487	0.388	960	491
	Site 4	1521	767	0.564	0.169	0.708	0.103	615	457	1.475	0.163	906	309

first and the second sampling periods.

4. Release Rate of Nutrients were 0.86~8.63 mgP/m^2day in 1st sampling period, 0.05~0.70 mgP/m^2day in 2nd sampling period and 4.99~36.56 mgN/m^2day in 1st sampling period, 8.56~19.86 mgN/m^2day in 2nd sampling period. Compared with nitrogen and phoshporus release rate, release rates of nitrogen were greater than release rate of phosphorus. And, nutrients release rates for the 1st sampling period were greater than those for the 2nd sampling period. According to the result, release rates were measured highly in the temperature rising season and showed distinctive characteristics of sampling sites.

5. TP contents of sediment were 807~1542 μg/g in the 1st samples and 677~5238 μg/g in the 2nd samples. TP at Hoenam and Chusori were 1382~5238 μg/g and 772~1360 μg/g. Inorganic phosphorus was proportional to the TP content. Overall, phosphorus relaese rate and phosphorus content in sediment were not interrelated in so much.

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