Analysis and Evaluation of Lake Sediment

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Abstract

This study was performed to estimate interrelation between characteristics of sediment and nutrient releare from sediment in Dae-cheong lake. For the investigations, sediments were sampled in June and October 1997 at fish farms, embayment, and the main stream of Dae-cheong lake. Items for investigation are as follows; water content, weight loss on ignition(IG), porosity of sediment, Total Kjeldahl Nitrogen(TKN), content of element(H, N, C), nutrient release rate. Water content and porosity were measured to conjecture the physical trait and grain size. And weight loss on ignition was measured to determine the contents of organic substance. For the determination of nutrient release rate, PO_4-P and NH_4-N concentration of interstitial water and overlying water were measured. Release rate of nutrients which has direct influenced upon the water quality were 0.05~8.63mg-P/m^2·day and 4.99~36.56mg-N/m^2·day. And it was found that release rate was measured higher in the 1st sampling than in the 2nd sampling. And for determination of the humus level of sediment, carbon and nitrogen content were measured by using elemental analyzer. Generally, C/N ratio is used to determine humus level of lake sediment. As a result of elemental analysis, C/N ratio was determined in the range of 7.64~11.55, so humus level of Dae-cheong lake sediment was estimated from mesohumic state to oligohumic state.

keywords : lake sediment, humus level, nutrient release rate

I. Introduction

In a geological perspective, lakes may be regarded as temporary objects on the surface of the earth. As for geomorphological or biological species, lake exit in three successive stages: youth, maturity and old age.

Allochthonous nutrient like as domestic sewage and industrial effluent from factory were deposited on the lake bottom. And many limnologists have studied to correlate between water quality and trophic state of lake. Trophic levels are classified into three groups: oligotrophic, eutrophic, dystrophic. Trophic types of lake depends on the relationship between the supply of organic matter from autotrophic and allotrophic source. As important as trophic level of lake by water quality, sediments located in lowest bed of lakes are important role in deciding trophic state of lake. Sediment types, like lake types, can be classified according to several principles and many sediment parameters. In terrestrial sedimentologies, sediment classification can be based on numerous sediment characteristics, like color, structure, grain size, organic content, algal content, and benthic community. And study area of sediments are divided in several groups; on the organic parts of sediment, on the physics and chemistry, on the mineralogy. An elaborate and useful classification was introduced by Hansen[1]. He differentiated by means of mineral grain size and dominant plankton groups. But, classifications by Hansen were confused to easily by non-experts. Nowadays, many geologist are using systematic classification organized by many experimental component; Weight loss on ignition, carbon, nitrogen, phosphorus, silicon and carbonate contents.

Like foreign countries, there are many man-made lake in our country. In 1960s~1970s, for the development of economy many multipurpose dams were constructed. After the construction of the dams, by large amounts of domestic swage and industrial effluents, water pollutions has become major issue of national aspect. Day by day, 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 the allochthonous nutrient sources for the past several decades. Recently, however, controlling the release of nutrients from sediment is becoming an increasing concern since the nutrient concentration of sediment in stagnant 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. And in Dae-cheong lake, there are many fish farms before 1996. In fish farm, many fisher 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 lake bottom.

In this paper, we discussed for estimation of nutrient release rate using mathematical model. In this work, we used Fick's diffusion law to calculate the release rate of nutrients. Mathematical model used for calculating the NH_4-N and PO_4-P gradient between the overlying water and the interstitial water in the uppermost layer of sediment was well applied. And the method for estimating flux from lake sediments are classified into two steps. In first step, nutrient flux is estimated from the measurement of the concentration of overlying waters and interstitial waters. In the second steps, flux is calculated from Fick's law, i.e., flux is proportional to the gradient of nutrient concentration at the sediment-water interfaces.

In addition to the release rate of nutrients, humus lev
el of sediments were predicted by using Hansen's method[2]. Hansen concluded in his paper in 1959 that if the content of organic carbon less than 50% and C/N ratio less than 10 the humus is neutral, and if the content 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 the humus 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. So, by using of Hansen's theory we make an effort to deduce humus level of Dae-cheong lake sediment for the final results of this paper. And, comparing the release rate of nutrients we could indirectly estimate humus level of sediment compared with C/N ratio determined by elemental analysis.

Ⅱ. Method

Sampling periods were chosen to compare the release rate difference between in summer and autumn. The first sampling were done from 16 June to 20 June and the second sampling were done from 15 October to 20 October 1997. And, sampling sites were selected for comparing the regional characteristics of lake. So We could select 4 sampling sites; at fish farms in Hoenam, embayment in Chudong and Chusori, and the main stream in Munee. Instruments for sampling were Core Sampler(Wild Co., U.S.) of which column dimension is 4.8cm(i.d.) x 50cm(L.).

Table 1. Hydrological Characteristics of Dae-cheong Lake

Parameter	Dae-cheong Lake
Basin Area	4,134 km^2
Watershed Area	72.8 km^2
Watershed Length	86 km
Maximum Volume	1,490 x $10^6 m^3$
Effective Volume	790 x $10^6 m^3$
Mean Inflow Volume	2,677.4 x $10^6 m^3$/year

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.

1. Water Content and Porosity

A column of sample was cut by 0~2 cm and top layer was centrifuged to take out interstitial water 30 min at 3000 rpm. The samples which was centrifuged were dried at 105~110℃ until the weight loss is constant. Water content is calculated from the weight loss after cooling the dried sediment to the room temperature in desiccator. And, porosity of sediment was calculated by the ratio of the pore volume divided by the total volume of the sediment. The pore volumes were estimated by using the water content. And the total volume of the sediment was the sum of the water volume determined by the water content and the volume of dried sediment.

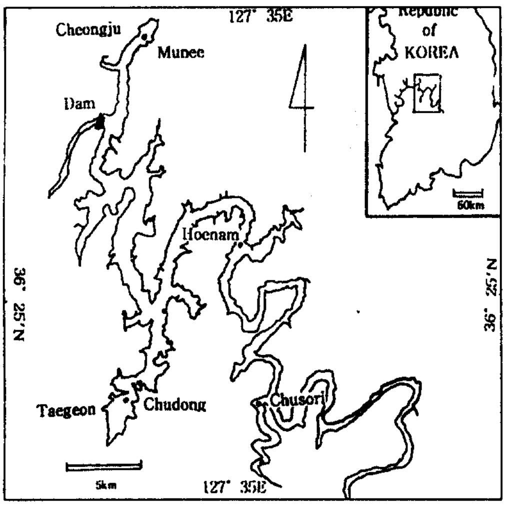

Fig. 1 Site Map

2. Nutrients Release Rate

To determine the nutrients concentration in interstitial water, columns of sediment sample 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 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[3], respectively.And, nutri ents release rates from the sediment are calculated using the method based upon Fick's diffusion law[4], which is

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

where

Φ : porosity of the sediment

D_t : diffusion coefficient (m²/day) of a nutrient at t℃

C_i : concentration (mg/m³) of a nutrient in the interstitial water of the surface sediment

C_w : concentration (mg/m³) of a nutrient in the overlying water

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

As 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 determ ined by many researchers are used to calculate the effective dispersion coefficient.

$$D = D_o \cdot \Phi^2 \quad \text{--------} \quad (2)$$

D : effective dispersion coefficient (㎡/d)

D_o : molecular diffusion coefficient(㎡/d) when $\Phi=1$

The molecular diffusion coefficients of NH_3 -N and PO_4-P used in this study are 8.5 x 10^{-5}㎡/day and 5.3 x 10^{-5}㎡/day, respectively. Diffusion coefficient is corrected as in the equation (3) since it depends on temperature.

$$D_t = D \cdot (1 + a \cdot t) \quad \text{--------} \quad (3)$$

D_t : diffusion coefficient(㎡/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.

3. Loss on ignition and Total Kjeldahl Nitrogen

Loss on ignition was determined by measuring the weight loss after igniting the dried sediment (ca. 10g) at 550℃[5] for 1 hours in electric furnace. And the total organic nitrogen contents were determined by Semi-micro Kjeldahl method[6]. Digestions of sediment samples were conducted in Kjeldahl flask with a total capacity of 800mL. First, a certain portion of sediment added in Kjeldahl flask with conc-H_2SO_4. And for promotion of digestion 6.7g K_2SO_4 and $CuSO_4$ 0.365g(ca. K_2SO_4:$CuSO_4$ = 20:1) were added respectively. And Kjeldahl flasks were boiled briskly until sample's color changed like as pale-green. After digestion, samples were filtered by GF/C filter using vacuum pump. Filtered solutions were marked with distilled water to 100mL. In them 10mL of filtered solution with conc-NaOH solution were put in distillation apparatus. Distillated solutions were collected in receiver mass cylinder contained boric absorbent solution. Received solutions were titrated with H_2SO_4 solution.

4. Carbon and Nitrogen Contents by Elemental Analysis

For the determinations of C/N ratio, carbon and nitrogen contents of the dried sediments were measured using elemental analyser. Major principle of elemental analyzer is dynamic combustion method like that; the sample weighed 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 quartztube. Gas which has passed catalytic layer is transferred into the gas chromatic column and then each single components are separated.

Ⅲ. Results and discussion

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 content, and porosity of surface sediments were measured as in Table 2. The depth of water at the sampling sites were 17~25m. The depths of sediment were 11.0~29.0cm and the water contents were in 41.0~70.0%. The porosities were 64.6~84.6%. By these measurements it can be guessed that the sediment of Dae-cheong lake is composed of silt or clay.

Table 2. General survey of sediment samples

Sites \ Item	Mean depth of water (m)		Sediments depth(cm)		Water content of sediment (%)		Porosity (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Munee	20	19	11~17	15~20	59~63	51~70	79.0	76.5
Chudong	16	15	14~29	12~16	56~62	45~53	79.3	85.9
Hoenam	28	25	14~24	13~25	54~59	45~49	76.7	69.5
Chusori	23	21	18~27	20~21	51~68	41~66	84.6	64.6

2. 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 3 and Table 4. 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 overlying water were determined in the range of 0.02~1.531mg/L and 0.005~4.471mg/L, respec tively. As shown in Table 3, in most areas except Munee, the NH_4-N release rate were measured higher in the 1st samples than the 2nd samples, which indicates that NH_4-N was released from sediments as the degradation process progressed during water temperature stratification season.

Table 3. 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

From the results, it was found that NH_4-N and PO_4-P concentrations in the interstitial water are relatively high in fish farms such as Hoenam area and in the embayment such as Chusori area. Especially, Chusori area in the first sampling period, NH_4-N and PO_4-P concentrations in the interstitial water were measured most highly. So, we could guess that anaerobic condition of the lake bottom is mainly due to the accumulation of organic matter originating from fish farming and of the incoming materials during the flood. And, it was generally known that effective components of influencing release rate are interstitial and overlying water concentration and porosity, temperature and 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 in autumn because of low hyperlimnion temperature and low degradation rate of organic materials. The internal loadings of phosphorus at the embayment area and at fish farms could be important judging from high PO_4-P concentrations and the phosphorus release rates as seen in Table 4.

Table 4. Release rate of DRP and NH_4-N in samples

Item / Sites	Diff.coeff. of phosphorus ($x10^5 m^2/day$)		Release rate (mgP/m^2day)		Diff.coeff. of NH_4-N ($x10^5 m^2/day$)		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

3. Determination of trophic state

Generally, loss on ignitions were used to estimated organic contents of soil and sediment. In this study, we calculated the loss on ignitions by using the difference of weight after digestions. IGs were measured in the range of 9.9~10.7% in the 1st sampling period and 2.4~10.8% in the 2nd sampling period as shown in Table 5. And also, it was found that weight loss on ignition increases as the depth of sediment increases. And IG values of the 2nd samples were measured in some higher than the 1st samples and so it can be conduced that the sediment of Dae-cheong lake 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 such as in Hoenam and estuaries such as in Chusori. Viewing the result of IGs, we could predict the tendency of TKNs and C/N ratios. TKNs of the 1st samples were 0.093~0.265% and were comparatively high at Hoenam and Chusori area. And also, TKNs of the 2nd samples were 0.188~0.283% and were comparatively high at Hoenam and Chusori area. In Hoenam area, because many fish farms were located in this area before 1996, much fish excrement were deposited on the lake bottom. In Munee and Chudong areas, TKNs were measured in the scope of 0.093~0.188% and this values were lower than those of Hoenam and Chusori areas. And compared with each sampling periods, values of the second sampling periods were measured in some higher than the first sampling periods. In this result, it could be conjectured that during flooding season much of organic materials were induced in lake and deposited on the bottom of lake. The characteristics of TKN were shown similar trends in nitrogen contents of elemental analysis. And, humus level of sediment is an important factor for estimating the nutrients release from sediments and trophic state of sediments. According to Håkanson[7], 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 TKN 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 below than 10%, so we could guess that C/N ratios were well fitted than IG/TKN ratios. In this study, for determining the humus level of sediments, C/N ratio calculated by 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 5.

Table 5. IG and TKN, C/N ratio of sediment samples

Items / Sites	IG(%)		TKN(%)		Carbon (%)		Nitrogen (%)		C/N ratio	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Munee	9.9	10.4	0.14	0.18	1.75	1.621	0.152	0.175	11.553	9.26
Chudong	9.6	10.	0.09	0.17	1.65	1.415	0.177	0.185	9.355	7.64
Hoenam	11.6	11.	0.26	0.28	1.64	1.935	0.187	0.225	8.791	8.60
Chusori	10.7	10.	0.23	0.24	1.98	1.472	0.183	0.187	10.841	7.87

Nikaido[8] suggested in his published paper in 1978 that the sediment with lower C/N ratios contain a larger amount of easily decomposable organic matter than the sediment with higher C/N ratios. Comparing the result of C/N ratios, C/N ratios of the 2nd samples after flooding season were determined higher than that of the 1st samples. This means that much of organic matter included in the reservoir during the flooding season. And compared with C/N ratio and nutrient release rate, as reported in Koyama's paper[9] in 1966, the higher the C/N ratio of the sediment the mineralization rates of organic substance were faster than lower C/N ratios. As shown in the Table 5, the C/N ratios were in some higher in most area in the 1st sampling period than that of the 2nd sampling period. This means that the release rate of nitrogenous nutrient of the 1st samples would be faster than that of the 2nd samples.

From the correlations between the nutrient release rate and the C/N ratio, we could predict the tendency of trophic state of sediment. As a result of C/N ratios, trophic states of sediments in Dae-cheong lake was estimated in oligohumic and mesohumic states like shown in Figure 2.

V. Conclusion

1. The depths of sediment were 11.0~29.0cm and water contents were 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.

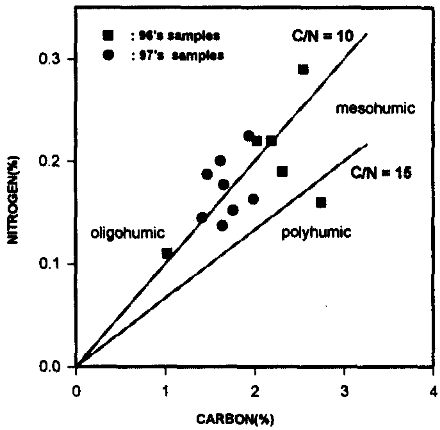

Figure 2. Nitrogen content varsus carbon in sediment samples from Dae-cheong lake

2. Release rates of nutrients were 0.86~8.63mg-P/m^2·day in the 1st sampling to 0.05~0.70mg-P/m^2·day in the 2nd sampling and 4.99~36.56mg-N/m^2·day in the 1st sampling to 8.56~19.86mg-N/m^2·day in the 2nd sampling. Compared with nitrogen and phosphorus release rate, release rates of nitrogen were greater than that of phosphorus. And being compared with sampling period, nutrients release rates of the 1st sampling period

   were greater than the 2nd sampling period. According to the result, release rates were measured highly in the temperature stratification season and showed distinctive characteristics of sampling sites.
3. IG values during the first and the second sampling were in the range of 9.6~ 10.7% in the 1st sampling and 10.4~11.8% in the 2nd sampling. Organic contents which were calculated by weight loss on ignition were in scope of 10% in most sampling sites. TKN values of the 1st samples were 0.093~0.265% and was comparatively high at Hoenam and Chusori area. At Hoenam area, many fish farms were located until 1996 and so much fish excretion was accumulated for a long time. And TKN values of the 2nd sampling were measured in the scope of 0.178~0.283%. Like as in the 1st sampling period, Hoenam and Chusori area was relatively higher than other sites.
4. Carbon to nitrogen content ratios for the 1st samples were 8.791~11.553, and C/N ratios of the 2nd samples were measured below than 10, in scope of 7.648~9.262 in most areas. It implies that the humus level of sediments would be changed for an interval of three month between the first and the second sampling periods.

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