THE DECOMPOSITION OF CELLULOSE IN LAKE SOYANG,KOREA

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ABSTRACT

For elucidating the degradation rates of phytoplankton, part of carbon cycle, the rates of cellulose breakdown were investigated at two sites in Lake Soyang. Cellulose films stained with Rmazol brilliant blue R were used as the substrate. The degradation rates were ranged betweeen 0.1-100 %. In summer and autumn, the cellulose films were completely decomposed in epilimnion of fish farm site, but only about 30 % of the dam site. The perfect degradation of cellulose at the fish farm site were due to the fish feed, which contains phosphate, and showed the possibility of new indicator of eutrophication. At the metalimnion, the rates were higher than other depth in summer and autumn.

KEY WORD : Lake Soyang, cellulose, carbon cycle, fish farm effect

INTRODUCTION

The sources of organic detritus in the aquatic habitats are external and internal. Allochthonous detritus comes from all different sources such as leaf litter, sewage effluent and municiple waste water. Autochthonous detritus is internally generated primarily by algae and by macrophytes, therefore, the total amount of organic material is increasing with eutrophication, which is uncontrollable (3). Regardless of its origin, detritus is constantly decomposed to dissolved organic matter which is used as the basic food sources of aquatic ecosystem. In large lakes, such as the Lake Soyang, organic materials are autochthonous organic production by phytoplankton and macrophyte (4).

Cellulose, the cell wall component of phytoplankton and macrophyte, is the major constitutent of autochthonous organic materials and particularly abound in lakes (15). Cellulose can be degraded by aerobic and anaerobic processes in sediments and water column (14).

Lake Soynag is the largest artificial reservoir in Korea. Recently, the water quality is going worse by the eutrophication. In spite of negligible input of waste water into the lake, dense local bloom of a dinoflagellate, Peridinium bipes, was reported every year near the inlet of major streams in early summer and late autumn(10). Moreover, average chlorophyll a concentration in the surface 5 m was about 14 ug/l which showed the constant increasing rate, 0.4 ug/l/yr and large number of Anabaena sp. was also observed at the main stream in autumn (9). And the major source for phosphate is fish feed which contains 2-3 % of phosphate.

In order to investigate the degradation rates of phytoplnkton detritus in the Lake Soyang, the degradation of cellulose were determined at two sites.

METHODS

Study sites

Within the Lake Soyang, two sites were chosen; Dam site, the deepest point, is located infront of dam, and fish farm site is in the middle of netcage type fish farm (Fig. 1).

Degradation rates of cellulose

The degradation rates of cellulose in water column were examined with cellulose films (2 x 5 cm) stained with Remazol brilliant blue R (13), from September 1987 to November, 1989. Duplicated strips were submerged in the water column at the depth of 0, 1, 3, 5, 7, 10, 15, 20, 30, 50, 60, 70, 80 m (at the dam site only) and bottom. After ca. 2 months (two cases, 3 months) exposure, the strips were retrieved and residual dye was extracted, and the percent weight of cellulose lost was calculated (6).

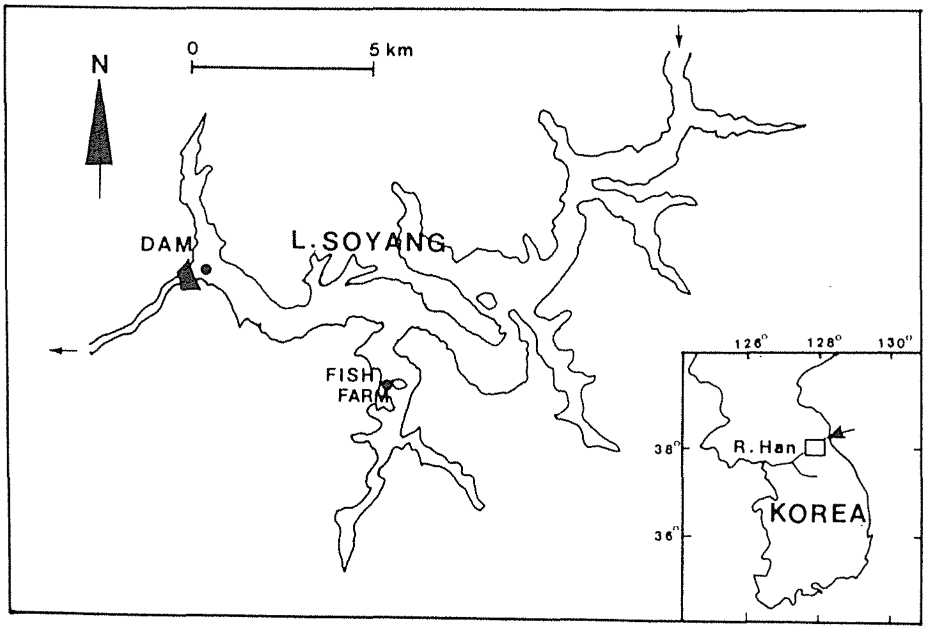

Fig. 1. Map showing the study site in Lake Soyang.

RESULTS

The typical profiles of cellulose degradation are shown in Fig. 2. At the dam site, the degradation in metalimnion were quite contrasted with those at epilimnion and hypolimnion. The degradation rates during two months submersion appeared to be 17-35 % in epilimnion, 45-64 % in metalimnion and 35 % in hypolimnion. While at the fish farm site, the rates in the same period were about 100 % in epilimnion, 56-73 % in metalimnion, and 45-49 % in hypolimnion.

The degradation rates of cellulose in Lake Soyang were shown in Table 1. In winter (from December, 1988 to Feburary, 1989) the profiles of breakdown rates at both sites were similar except the upper layer (0-2 m depth). At the dam site, the rates were constant to 10 m depth (about 20 %), while at the fish farm site, the rates at 0 m , 1m depth were high as 40.8 %, 32.4 %, respectively.

In the metalimninon of dam site, the rates were higher than in epilimnion and hypolimnion. For instance, the duration between October, 1988 and December, 1988, the rate at 10 m depth was 73.6 %, while the rates at surface were 18.0-32.0 %. This phenomena were occured in many cases exept winter submersion.

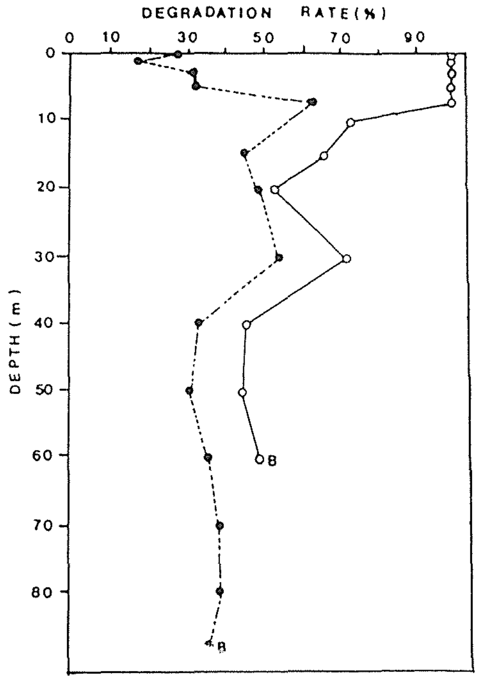

Fig. 2. The typical profiles of cellulose degradation. High rates were appeared at 10-30 m depth of dam site (●) and 30 m at the fish farm site (o). Exposure duration was from 22 June 1988 to 19 August 1988.

Table 1. The degradation rates of cellulose at dam and fish farm site in Lake Soyang.

Duration	1987. 7.28 - 9.22		1987. 9.22 -12.28		1988. 2.29 - 4.29		1988. 4.29 -6.22		1988. 6.22 - 8.19		1988. 8.19 -10.26	
depth	dam	fish	dam	fish	dam	fish	dam	fish	dam	fish	dam	fish
0 m	34.1	97.1	50.2	99.9		20.2	-	91.5	27.5	100.0	-	100.0
1	32.8	98.5	47.8	99.9	8.8	2.1	-		17.4	100.0	-	100.0
3	21.1	94.6			7.6	6.4	-	93.6	32.2	100.0	-	100.0
5	29.5	92.4	80.3	99.9	7.9		-	43.0	34.5	100.0	-	100.0
7	24.8	95.4	43.7	99.9	7.3	6.4	-	19.9	63.8	100.0	-	98.4
10	22.4	88.4	50.6	99.9	5.6	7.6	-	13.7		73.0	-	82.0
15					14.6	13.7	-	5.8	45.8	65.9	-	62.5
20	31.0	87.1	40.4	99.9	17.3	4.7	-		49.0	55.9	-	71.8
30	34.5	39.4	45.2	99.9	27.5	7.9	-		54.5	71.5	-	79.2
40					18.5	5.3	-	3.4	33.6	46.2	-	92.7
50	37.4	37.4	19.9	30.1	21.6	27.2	-		31.0	44.8	-	62.7
60					18.7		-		35.9		-	46.9
70					16.7		-		38.8		-	
80	34.1		28.9		17.3		-		38.8		-	
bottom	39.4	40.1	20.2	14.6	15.8	15.2	-		35.9	49.3	-	15.9

Table 1. Continued.

Duration	1988.10.26 -12.26		1988.12.26 -89. 2.20		1989. 2.20 - 4.27		1989. 4.27 - 6.28		1989. 6.28 -8.19		1989. 8.19 -11.29	
Depth	dam	fish	dam	fish	dam	fish	dam	fish	dam	fish	dam	fish
0 m	18.0	65.6	20.4	40.8	6.8	3.8	8.5	52.6	6.2		0.4	72.2
1	32.0	60.4	23.6	32.4	1.7	2.7	5.1	37.4	5.1	92.4	0.1	73.0
3	44.8	61.2	23.2	19.2	4.8	2.7	7.4	50.5	11.9	84.7		92.2
5	49.6	96.0	21.6	15.2	7.1			43.6	14.6	52.0		96.0
7	50.4	56.0	22.0	24.8	4.1	3.1	25.4	31.5	20.0	59.0	7.5	
10	73.6	36.0	23.6	11.2	3.1	3.1	7.5	25.1	26.8	66.0	12.5	89.0
15	60.4	68.0	9.2	14.8	2.7	10.9	6.2	3.6	21.0	42.9	12.3	84.4
20	58.4	47.2	9.6	26.0	6.8		5.9	5.1	29.9	23.2	76.6	50.5
30	54.8	34.0	17.2		7.8	11.9	8.0		20.1	23.7	53.1	62.3
40	57.6	24.8	5.2	23.6		4.1		3.0	11.3	7.7	60.1	69.1
50	36.8	37.2	2.0	5.2	18.4	7.9	9.0			6.3	34.5	57.9
60	2.8	28.0			16.7		7.9	14.1	6.4		26.9	
70	54.8				13.6		4.9		6.9		14.8	
80	36.8				8.2				4.8		2.6	
bottom		36.4	0.4	42.0	5.1	16.0	7.2	11.0	10.9	15.4	47.0	

DISCUSSION

The microbes play a role as primary decomposer in aquatic ecosystem. They can utilize the dissolved organic substances (DOM) at low concentrations and also assimilate dissolved inorganic nutrients such as nitrate and phosphate (2). DOM is the major form of organic material in aquatic environment, and is converted from particulate form (POM). The POM is transformed stepwise into DOM by autolytic enzymes, exoenzymes of fungi and bacteria(5).

The breakdown of particulate organic compounds depends on extracellular enzyme activity, which proceeds faster under warmer conditions. But, low temperature do not halt the decomposition. Even under ice cover lake, the POM decomposition proceeded (17). At the fish farm site, the perfect degradation of cellulose strips in the surface layer was due to the fish feed which contains 2-3 % of phosphate. The phophorus loading from fish farm was reported about 36 tP per year, on the other hand, that from watershed about 45 tP per year (7). Since the phosphate supply for microbes was abundant at the fish farm site, the cellulose strips were fully decomposed in summer and about 40 % in winter.

Therefore, high temperature (about 20-30 °C) and the nutrient from the fish feed speeded up the rate of cellulose breakdown at the fish farm site in summer. And the phytoplankton debris are thought to be completely decomposed before they were precipitated on the sediment. However, at the dam site, the phosphate limitation was responsible to slower degradation in the surface layer.

The high rates in metalimnion can be explained by precipitaion and exoenzyme regulation. The annual average precipitation in Korea is about 1,200 mm, and half of it precipitate in summer. In Sept. 1, 1984, heavy rain had fallen (260 mm/day). A month later, the high turbidity values (34-51 NTU) were observed in 20-50 m depth (7). This result indicates that during the rainy season, the inflowing water, which contains large amount of clay particles, detritus, watershed topsoils and microbial zymogenous species, intruded into the metalimnion. Particle bound bacteria are primarily responsible for the microheterotrophic activity in the water culumn of fresh water(11). And the presence of clay mineral increased the efficiency of substrate transformation by marine bacteria (18), and decreased the predation and parasitism pressure on bacteria(16). During the study period, the total bacterial number, heterotrophic bacterial number, proportion oF beta-glucosidase releasing bacteria, values of electron transport system activity were higher than those in epilimnion and hypolimnion(1). Moreover, and low values of dissolved oxygen in metalimnion were also reported(8). These results suggest that the microbes actively regenerate, respire and metabolize the product of cellulolysis in metalimnion.

Another possible explain is exoenzyme regulation. The degradation of cellulose is initiated by the cellulolytic microorganisms, regarded as "primary microorganisms" (fungi and/or bacteria). The initial products of cellulose breakdown are cellobiose and glucose, which are utilized by the primary microorganisms for cell materials and for energy source. In natural environment, the primary microorganisms are closely associated with a very diverse population of "secondary microorganisms" that are unable to hydrolyze cellulose but use cellobiose, glucose, and other free sugars for energy source. Although the secondary microorganisms depend on the primary microorganisms, the former also help the latter by removing free sugars, which normally are inhibitory for the degradation of cellulose. Thus, this symbiosis promotes cellulose degradation (12).

The allochthonous clay materials and zymogenous microbes in inflowing water made the suitable conditions for the microbial growth and metabolisms. Moreover, the water stratification might change the sinking velocity of organic detritus from epilimnion, and by autolysis, the nutrients for microbal growth and metabolisms might be supplied. So in metalimnion, the microbes (primary and/or secondary microorganisms) actively consumed the products of cellulose breakdown for their growth and metabolism. As the products of cellulose decomposition were disappeared, the primary microorganisms were stimulated to decompose the added cellulose strips.

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