Rep. Suwa Hydrobiol., 9; 69~75 (1995)
Proceedings of the 7th International Symposium on River and Lake Environments, 1994, Matsumoto

The distribution of attached bacteria on cellulose film and cellulose degradation rates in Lake Soyang, Korea.

Tae-Seok AHN, Seung Ik CHOI And Ho Wan PARK
Dept. of Environmental Science, Kangwon National University, Chunchon, 200-701, Korea, Fax;+82-361-51-3991.

INTRODUCTION

Organic compounds in large lakes are derived from phytoplankton and macrophyte, and these autochthonous organic materials are the major resultant of the eutrophication [4]. Cellulose, a cell wall component of phytoplankton and macrophyte is a major constituent of autochthonous organic materials and particularly abundant in lakes [13].

Attached bacteria are important for the remineralization of particulate organic matter [8] because they are more active than free-living bacteria [6]. They assimilate low concentration of organic materials and nutrients into high quality food for predator [7].

The purposes of this study were to define the cellulose degradation rates and the role of attached bacteria in Lake Soyang, which is in eutrophic state [2]

MATERIALS AND METHODS

Triplicate cellulose strips (2.5 x 5 cm) stainned with Remazol Brilliant Blue R [1] and duplicate strips in litter bag were submerged in water column and water-sediment interface of Lake Soyang, from January to November, 1992. After *ca.* 2 months exposure, the strips were retrieved and then blue and unstained strips were used to measure the cellulose degradation rates [5] and to estimate attached bacteria numbers [3,11], respectively.

RESULTS

The values of cellulose degradation rates and attached bacterial numbers are shown in Table 1. At first experiment (from 16 January to 19 March, 1992), cellulose degradation rates were 8.5 - 19.4 % in water column and 55.0 % in water-sediment interface (bottom). The attached bacterial numbers were 1.6 x 10^6 - 9.7 x 10^6 cells cm^{-2} in water colums and 1.5 x 10^7 cells cm^{-2}

in the bottom. The degradation rates were consistant with change of attached bacterial numbers.

At second experiment (from 19 March to 15 May), the degradation rates and bacterial numbers were the lowest. Only at 0 m, the bacterial number was 7.8 x 10^6 cells cm^{-2}, which was higher than those of first experiment. And at bottom, the bacterial number were half of the first experiment.

The changes in cellulose degradation rates and attached bacterial numbers at third experiment (from 15 May to 23 July) were quite different from first and second experiments (Fig. 1a). The degradation rates at 7 and 10 m depths were the highest values, 80.7 and 75.5 %, respectively. And below 20 m, the degradation rates were about 20 % and decreased with depth. Attached bacterial numbers were consistent with the change of cellulose degradation rates except for bottom sample. Curiously at the bottom, only 1.2 % of cellulose was attacked, while attached bacterial numbers was 2.5 x 10^7 cells cm^{-2}. During the period with high temperature (4th experiment, from 23 July to 21 September), at 0 - 2 m depths, the cellulose degradation rates were less than 10 %, and 5 - 20 m depths the rate were about 40 %. Below 20 m, the rates were changed with depth like other experiments. But in epilimnion (0 - 15 m), the cellulose degradation rates were reversely changed with attached bacterial numbers. At the bottom, the degradation rate was only 0.3 % similar to the third experiment, but the bacterial numbers was only 5.5 x 10^6 cells cm^{-2}, one fifth of the third experiment.

The degradation rates were reversely changed with bacterial numbers at the fifth experiment (Fig. 1b). The degradation rates were 20 - 30 % in epilimnion and hypolimnion. But in metalimnion, the rates were more than 40 %, especially at 40 m the rate was 83.4 % which was the highest rates in this study. The attached bacterial numbers at 0 m was 1.8 x 10^7 cells cm^{-2}, the highest value of 0 m. From 2 m to 60 m, the bacterial numbers were relatively constant with range of 6.2 x 10^6 - 7.5 x 10^6 cells cm^{-2}. In hypolimnion (70 and 80 m depths), the attached bacterial numbers were about three times higher than those of the above water column.

The variation patterns of cellulose degradation rates and attached bacterial numbers could be divided into 3 groups: epi-,

meta- and hypolimnion. The scattergram of degradation rates and bacterial numbers at three groups were shown in Fig. 2. In epilimnion, slope between two parameters was 0.02, which means that the cellulose degradation was due to the bacterial specific activities (Fig. 2a). In metalimnion, the slope was 0.05 which may suggest that the attached bacterial numbers were responsible for cellulose degradation (Fig. 2b). But in hypolimnion, there was no correlation between two parameters (Fig. 2c).

DISCUSSION

In aquatic ecosystem, the cellulose degradation is initiated by the extracellular enzyme activities excreted from attached bacteria [9]. The growth of attached bacteria and enzyme activities would depend on the water temperature, concentration of nutrients and other environmental factors. In the third experiment, the high degradation rates was probably due to the high water temperature. In contrast to this, when water temperature was low during the first and the second experiment, the cellulose were slowly degraded. Even in ice covered lakes, the degradation of organic materials was observed by Tison *et al.*[12]. At from 0 m to 5 m layer, the degradation rates were low in the 3rd and the 4th experiments, which suggests that the high intensity of radiation and high temperature may inhibit the bacterial growth and activity. The cellulose decomposer, Cytophaga-like bacteria are inactivated above 24 °C in Canadian lakes [5]. Eventhough the causative microorganisms were not defined in Lake Soyang, excessively high temperature (32 °C) may be one of the reason for low degradation.

The highest rate of cellulose degradation in 40 m of the 5th experiment (Fig. 1b) may be due to the precipitation and nutrient supply from hypolimnion. Not only high rate of cellulose breakdown but also the higher bacterial numbers, higher values of bacterial activities and lower concentration of dissolved oxygen in metalimnion were already reported [1].

The relationship between cellulose degradation rates and attached bacterial number were apparently different from each layer. In epilmnion, cellulose degradation was responsible to the bacterial activities. By the environmental factors, such as temperature, UV radiation, nutrient concentration and biological

factors such as bacterial species composition and competition with fungi could affect the bacterial activities. But in metalimnion, the cellulose degradation was due to the bacterial numbers. Because this layer is more stable than epilmnion, the specific activity for cellulose degradation seems to be constant, except for destratification period.

In hypolimnion, since the anoxic zone was periodically occured, temperature was constalntly low, and nutrient concentration was high [2], the major factor affecting to cellulose degradation might be anoxic condition. The humic acid and polyphenol substances form anoxic conditions are enzyme inhibitors [10, 14]. During the study period, only in May, the dissolved oxygen concentration was 8.9 mg l^{-1}, while other seasons were anoxic state. By this anoxic state, the enzyme activities were depressed and the cellulose was degraded slowly. Because the development of anoxic zone, and the difference of chemical compositions and quantity of humic acid, the cellulose degradation rates were widely varied (0.2 - 55 %) not correlated with attached bacterial numbers.

ACKNOWLEDGMENT

This study was partly supported from Research Center for Molecular Microbiology, Seoul National University.

REFERENCES

1.Ahn, T.S., 1991. The high rates of cellulose breakdown rate in metalimnion of Lake Soyang, Korea. *Verh. Internat. Verein. Limnol.* 25:1441-1445.

2.Cho, K.S., B. Kim and T.S. Ahn. 1991. Reports on the effects of fishfarm to lake water quality. KOWACO.

3.Choi, S.I., H.W. Park and T.S. Ahn. 1993. The cellulose degradation and distribution of attached bacteria on cellulose film in Lake Soyang. *Kor. J. Microbiol.* 31(5):452-457.

4.Godshalk, G.L. and J.W. Barko. 1985. Vegitative succession and decomposition in reservoirs. *In* D. Gunnison (Ed.) *Microbial process in reservoirs.* p 59-78. Dr.W. Junk Pulbl. Dordrecht.

5.Hoeniger, J.F.M. 1985. Microbial decomposition of cellulose in acidifying lakes of south-central Ontario. *Appl. Environ. Microbiol.* 50:315-322

6.Kirchman, D., and R. Mitchell. 1982. Contribution of particle-bound bacteria to microheterotrophic activity in five coastal ponds and two marshes. *Appl. Environ. Microbiol.* 43:200-209

7.Kirchman, D.. 1983. The production of bacteria attached to particles suspended in a freshwater ponds. *Limnol. Oceanogr.* 28:858-872.

8.Kogure, K. 1989. Attachment of aquatic bacteria-overview. p.131-134. Proceedings of 5th ISME, Kyoto.

9.Ljungdahl, L.G. and K.E. Eriksson. 1985. Ecology of microbial cellulose degradation. *Adv. Microb. Ecol.* 8:237-299

10.Münster, J. and R.J. Chróst. 1990. Origin, composition and microbial utilization of dissolved organic matter. p.8-46. *In* J. Overbeck and R.J. Chróst (ed.) *Aquatic microbial ecology; Biochemical and molecular approaches*. Springer-Verlag. N.Y.

11.Paul, J.H. 1982. Use of Hoechst dyes 33258 and 33342 for enumeration of attached and planktonic bacteria. *Appl. Environ. Microbiol.* 43:939-944

12.Tison, D.L., D.H. Pope and C.W. Boylen. 1980. Influence of seasonal temperature on the temperature optima of bacteria in sediments of Lake George, New York. *Appl. Environ. Microbiol.* 39:675-677

13.Wetzel, R.G.. 1983. Limnology, 2nd ed. Saunders College Publishers. N.Y.

14.Wetzel, R.G.. 1991. Extracellular enzymatic interactions; storage, redistribution, and interspecific communication. *In* R.J. Chróst (ed.) *Microbial enzymes in aquatic environments*. p.6-28 Springer-Verlag. N.Y.

Table 1. The cellulose degradation rates and attached bacterial numbers on cellulose films in Lake Soyang.

Depth	1st exposure		2nd exposure		3rd exposure		4th exposure		5th exposure	
(m)	C	B	C	B	C	B	C	B	C	B
0	10.1	1.6	4.4	7.8			3.0	2.3	20.6	18.3
1			7.2	2.9			6.9	6.0	23.0	5.0
3			9.4	2.5	8.8	5.6	29.7	3.5	25.2	3.5
5	12.9	4.0	8.8	2.9	32.0	10.2	53.8	9.2	30.4	6.7
7	14.4	4.2	8.4	1.8	80.7	22.8	35.6	6.4		
10	14.4	2.5	9.1	3.8	75.5	41.0	49.5	6.2		
15	11.9	2.1		3.2	31.7	29.7	40.3	8.8	25.5	7.5
20			1.6	1.8	20.8	11.5	30.7	16.4		
30	19.4	4.1	0.6	3.5	22.4	11.2	25.4	10.6	46.9	3.2
40	13.5	3.7	7.8	3.3	21.1	14.9	15.2	12.2	83.4	5.4
50	14.1	5.4	9.4	4.8	14.8	6.4	13.2	8.5	49.4	6.2
60	13.2	4.4	14.4	4.6			21.1	10.3	34.0	6.4
70	8.5	9.7			9.7	7.2	7.3	10.3	27.3	20.6
80					12.7	8.0	7.3	3.5	26.7	16.1
Bot.	55.0	14.8	54.7	7.4	1.2	24.9	0.3	5.5		

C: Cellulose degradation rate (%) during 2 monthes
B: Attached bacteria number ($\times 10^6$ cells cm^{-2})
1st experiment: from 16 January to 19 March, 1992
2nd experiment: from 19 March to 15 May, 1992
3rd experiment: from 15 May to 23 July, 1992
4th experiment: from 23 July to 21 September, 1992
5th experiment: from 21 September to 27 November, 1992
Bot.: Water-sediment interface
Blanks are due to the missing strips

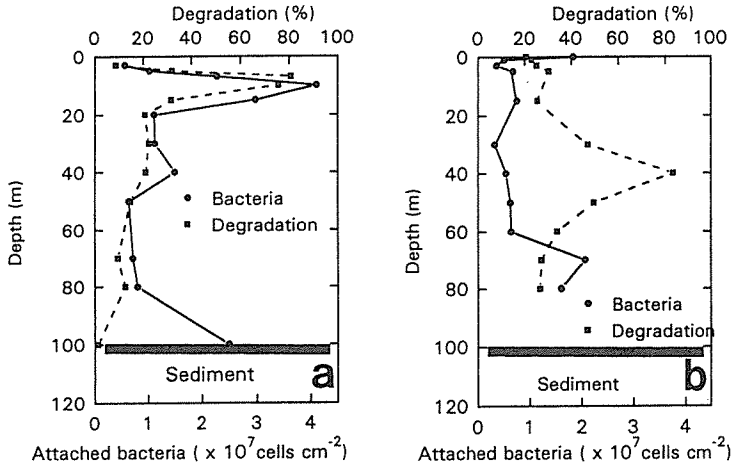

Fig. 1. The typical depth profiles of cellulose degradation rates and attached bacteria numbers on cellulose film in Lake Soyang. a) third exposure, b) fifth exposure.

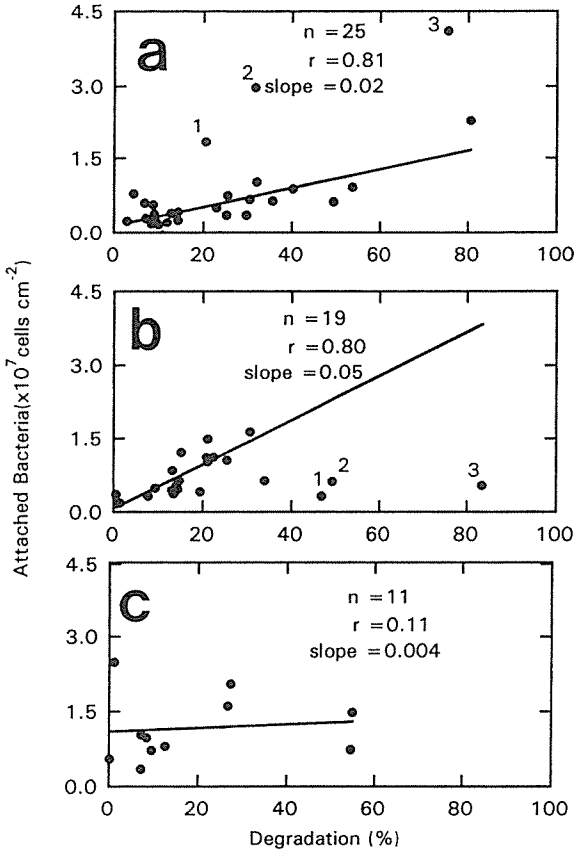

Fig.2. The scattergram of cellulose degradation and attached bacteria numbers in Lake Soyang. Numbered data are excluded for statistical analysis. a) surface layer (0 - 15 m), b) middle layer (20 - 60 m), c) bottom layer (70 m-bottom).