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Inlake algal bloom control with enclosure ecosystem bags

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Abstract— The enclosure ecosystem bags are used to study the control of algal bloom with the chemical and biomanipulation method and to test the phosphorus threshold value for algal growth. The bags with a value of 2.8 m^3 are filled with lake water and closely simulate the natural lake environment. The results showed that the application of aluminum and iron salts made the *Microcystis* colonies sink to the lake bottom and gradually die off, and as synergists, could greatly enhance the control of algicide. *Salvinia*, a kind of floating macrophyte, could also have inhibitory effects on the growth of *Microcystis*. 0.019 mg/L orthophosphate are regard as the threshold of *Microcystis* development. The mechanism of the effects of iron and aluminum salts were also discussed in the study.

Keywords: algal bloom; enclosure ecosystem bags; algicide; *Microcystis*.

INTRODUCTION

The feature of eutrophication is over massive development of blue-green algae or other plants in aquatic systems.

The key to control eutrophication is to reduce the nutrient concentration and to inhibit algae blooms in waterbodies. These measures can be carried out in these areas: in the catchment areas; at the inlet, including phosphorous elimination by using precipitation; flocculation and filtration or predam reservoirs; in the lake itself, including: (a) limitation or prevention of internal loading; (b) inlake control of algal development.

In this paper, by using chemical and biomanipulative measures, a study on the control of algal bloom was made with enclosure ecosystem bags, which could closely simulate natural factors, such as temperature, solar radiation, wind, vertical movements of water, background composition of water chemistry, biological structure, sediment setting and suspension. Chemical measure is sometimes used in treatment of eutrophication in drinking water supply waters. But, because of the toxicity of chemicals and the algal adaptation to algicides, this measure must be used with caution, especially when using algicides. Biomanipulation is due to the principle of food web and the competition of nutrient and energy in water. It is an important measure used to control algal development. Meanwhile, the research for the threshold value of affecting the development of *Microcystis* bloom will be discussed.

METHODS

All the experiments are carried out in enclosure ecosystem bags. These are 2 kinds of bags: the big and the small. Fig. 1 shows the shape of the big enclosure ecosystem bags. It is fixed in the steel framework which is floated by foamed plastics. The big bag consists of three layers of material: the outside layer is a net bag that is made of polyvinyl chloride (PVC) rope, the middle is a nylon bag; the inside layer is a bag that is made of nylon-ployethylene (20 mm nylon and 40 mm polyethylene). Moreover, a plate with sediment is hung inside the bag and it represents a lake bottom.

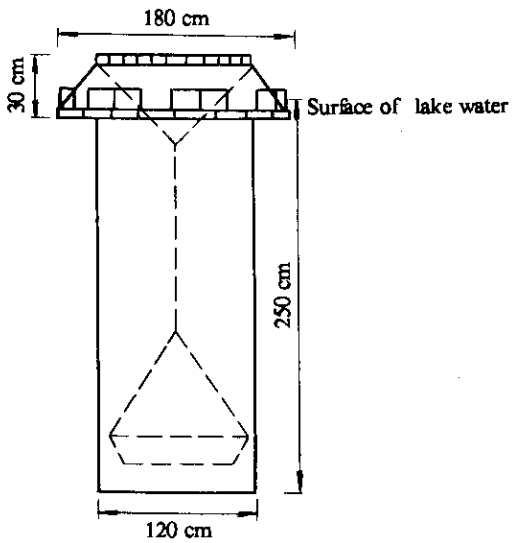

Fig. 1 The big enclosure ecosystem bag

Fig. 2 shows the construction of the small enclosure ecosystem bag. The small bag also floats on foamed plastic is installed in plastics plates without bottom. The bag is made of a compound membrane which consists of nylon-polyethylene (20 mm nylon, 40 mm polyethylene).

Chemical control algal bloom experiments have been carried out during three periods : from Sept. 23 to Oct. 8, 1987; from Aug. 28 to Sept. 7, 1988; and from Sept. 16 to Oct. 2, 1988.

The aim of the first chemical experiment of algal control is to determine the effect of algicides and the enhancement by Al and Fe salt. The experiments are conducted in 5 big enclosure ecosystem bags, in each of which a separate approach is applied (Table 1).

The second chemical control experiments are based on the results of the first experiments. They are carried out in 9 small enclosure ecosystem bags, and act as 9 different approaches (Table 1).

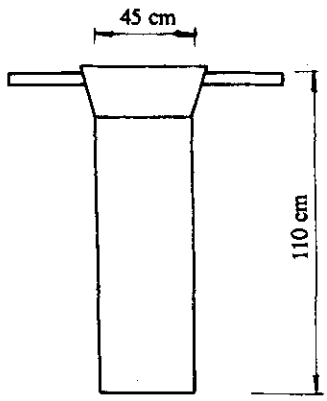

Fig. 2 The small enclosure ecosystem bag

Table 1 The approach of chemical control experiment

Number	Approach	Number	Approach
1	2 mg Cu /L	11	0.5 mg Cu /L, 15 mg Fe/L
2	1mg Cu/L, 15 mg Fe/L	12	0.8 mg Cu /L
3	7.5 mg Fe/L, 3.5 mg Al/L	13	0.8 mg Cu/L, 15 mg Fe/L
4	20 mg Fe/L	14	CK
5	CK	15	0.20 mg Cu/L
6	0.1 mg Cu /L	16	0.20 mg Cu /L, 2.2 mg Fe/L
7	0.1 mg Cu/L, 15 mg Fe/L	17	0.20 mg Cu/L, 5.2 mg Fe/L
8	0.3 mg Cu/L	18	0.30 mg Cu/L, 5.2 mg /L
9	0.3 mg Cu /L, 15 mg Fe/L	19	CK
10	0.5 mg Cu/L		

The third chemical control experiments are designed on the basis of the results from second experiments. They are carried out in 5 big enclosure ecosystem bags acting as 5 different approaches (Table 1).

Biomanipulation experiments are carried out in 2 big enclosure ecosystem bags. The experiment objective is *Salvinia*, a kind of macrophyte. The time is from Sept. 14 to Oct. 2, 1987. Two bags are two attempts:

Attempt 20 : 2.1 kg/m^2 *Salvinia* and sediment;

Attempt 21 : Control.

The study of the relationship between ortho-phosphate and the growth of algal bloom have been carried out in three big enclosure ecosystem bags. In order to remove suspended substances from the bags, 72 grams $FeCl_3 \cdot 6H_2O$ is put into the enclosure ecosystem bags. The result of flocculation is that most of the phosphorus and suspended substances precipitated to the bags

bottom. After 12 hours, the precipitate is pumped the bags, and then sodium bicarbonate solution ($NaHCO_3$) is put into the bags, the purpose of this is to neutralize the acidity caused by the hydrolysis of ferric chloride and to regulate water pH to 7. Because algae is partly removed in the flocculation process, about 0.1 m^3 of lake water is pumped to each bag in order to increase algal biomass. By putting different dosages of ortho-phosphorus into these bags, algal culture experiment could be implemented in the bags.

All water samples were taken from 20 cm deep water. Water temperature, pH and transparency are also determined while taking water samples. The biomass of algae is indicated by chlorophyll-a, and all chemical analysis methods are from " the Standard Method for the Examination of Water and Wastewater" (APHA, 1985).

RESULTS

1. Table 2 shows the result of the comparison between enclosure ecosystem bags and natural lake water.

Table 2 Comparison between some results in enclosure ecosystem bags with the corresponding data in nature lake water

	DO, mg/L	pH	Transparency, cm	*t*, °C	Dominant phytoplankton
The enclosure ecosystem bags	8.8	9.1	22.0	26.0	*Microcystis*
Natural lake water	9.0	8.8	20.0	26.0	*Microcystis*

Table 3 Changes of chlorophyll-a in the second control experiment (mg/m^3)

Approach	Date					
	9/16	9/18	9/20	9/22	9/27	10/2
6	76.08	116.00	161.55	49.06	32.04	33.90
7	2.26	0.47	2.85	2.99		
8	18.53	0.24	2.79	1.75	4.65	
9	40.86	0.70	0.93	2.05	1.90	9.13
10	91.52	1.07	4.08	1.40	6.18	24.83
11	22.85	0.23	0.00	1.23	0.66	0.33
12	170.52	4.21	3.67	3.07	1.42	
13	160.61	0.75	3.29	2.46	1.65	
14 (CK)	3.30	21.55	27.26	27.38	13.79	16.06

The data of Table 2 are based on the experiment of the 20th day, which demonstrates that there are little differences between in the bag and in natural lake water.

2 . Control of algae by chemical measures

Fig. 3 Shows the result of the first chemical control epxeriment with chemical measures. 7.5 mg/L Fe^{3+}+3.5 mg/L Al^{3+} and 20mg/L Al^{3+} could inhibit the growth of *Microcystis* better. Moreover, the results between Approach 1 and 2 are similar.

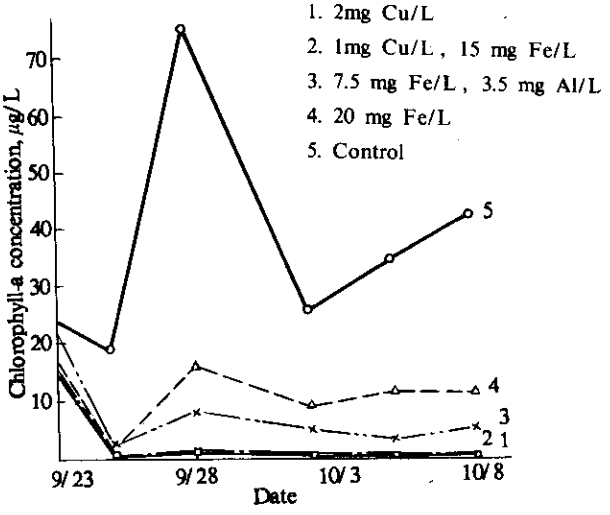

Fig. 3 Changes of chlorophyll-a in the first control experiment

Table 3 and Table 4 show the result of the second chemical control experiment. The control effect in these tables is calculated by the following equation:

$$E\ (\%) = \frac{Cb - Ca}{Cb} \times 100\ ,$$

Table 4 *E*-value in the second experiment (%)

Approach	Date				
	9/18	9/20	9/22	9/27	10/2
6	−52.47	−112.34	35.52	57.89	55.44
7	79.20	−26.11	−32.30		
8	98.70	84.94	90.56	74.91	
9	98.29	97.72	94.92	95.35	77.66
10	98.83	95.54	98.47	93.25	72.89
11	98.99	100.00	94.62	97.11	98.56
12	97.53	97.85	98.20		
13	99.53	97.95	98.47	98.97	
14 (CK)	−553.03	−726.06	−729.70	− 317.88	−386.67

where E is the control effect of chemical treatment; Cb is the chlorophyll-a concentration before treatment; Ca is the chlorophyll-a concentration after treatment.

The results showed that iron salt could greatly enhance the effect of algicide, and 0.3 mg / L Cu^{2+} (Approach 8) can effectively kill the *Microcystis* bloom.

The third result of the chemical control experiment is shown in Table 5 and Table 6, 0.2 mg/L Cu^{2+} (Approach 15) have a certain degree of toxicity to *Microcystis* bloom.

3. Biomanipulation for the control of algal development

Salvinia was chosen as the object of study. The result of the experiment are shown in Fig. 4.

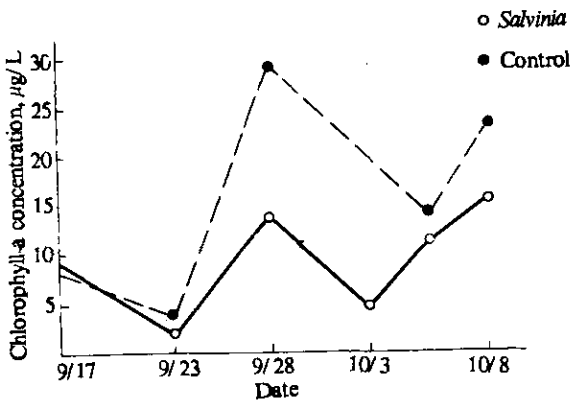

Fig. 4 Change of chlorophyll-a in enclosure ecosystem bags treated with *Salvinia*

Table 5 Changes of chlorophyll-a in the third chemical experiment (mg/m³)

Approach	Date				
	8/28	8/29	9/1	9/4	9/7
15	412	10.75	1.78	1.34	3.73
16	412	4.00	2.68	1.19	10.04
17	412	25.58	10.23	0.42	6.17
18	412	2.73	1.88	1.41	4.87
19 (CK)	412	205.23	164.23	37.20	32.40

The difference in inhibition effects in the two approaches is remarkable. Moreover, microscope observation showed that there is more zooplankton in Attempt 20 than it in Attempt 21.

4. The relationship between ortho-phosphate and development of algal bloom

In the season of the experiment, the weather and other environmental conditions in the lake is quite suitable for algae development. It is found that after 10 days, the algal biomass show

Table 6 E-value in the third chemical control experiment (%)

Approach	Date			
	8/29	9/1	9/4	9/7
15	97.39	99.57	99.67	99.09
16	99.03	99.35	99.71	97.56
17	93.79	97.52	99.90	98.50
18	99.34	99.54	99.66	98.82
19 (CK)	50.19	60.14	90.97	92.14

significant difference in the enclosures with different P-concentration, indicating that the phosphorus is limiting the growth of algae. Fig. 5 shows the chlorophyll-a concentrations versus P-concentrations in the enclosure after 12 and 17 days. In Fig. 5, there are clearly two groups of data: one is more horizontal at the ortho-phosphate concentrations above 0.02 mg/L and the other is more vertical. The regression analysis of the data produces two dashed lines in the figure.

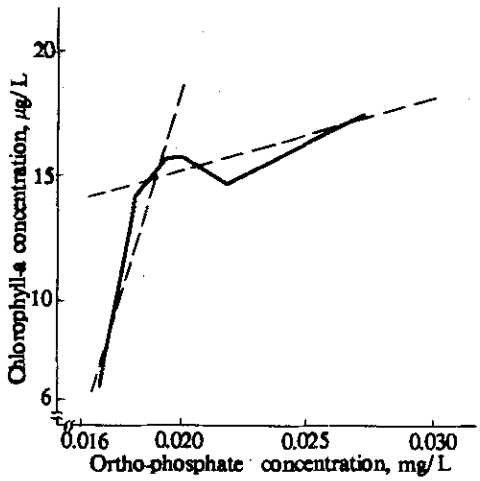

Fig. 5 Relationship between ortho-phosphorus concentration and the development of *Microcystis* bloom

The linear regression equation of the left three points is

$$Y=3452X-50.33, \qquad r=0.95,$$

and the equation of the right five points is

$$Y=286.7X+9.47, \qquad r=0.82.$$

The two lines intersect at the point of 0.019 mg P/L, which, we believe, represents the threshold concentration of algal growth in eutrophic Chaohu Lake. In the season of the experiment, the dominant algal species is *Microsystis*, therefore, the threshold concentration is mainly for *Microcystis*.

DISCUSSIONS

Because of the chemical reaction of iron and aluminum salt, Fe^{3+} and Al^{3+} can change the acidity of natural water, the pH value can raise with hydrolysis of Fe^{3+} and Al^{3+}.

Fig. 6 shows the change of pH in the first chemical control experiment. The pH value in natural water (control) is obviously higher than in approaches. The low pH in approaches leads to the percentage of Cu^{2+} in Cu (II) to increase greatly, and the *E*-value (control effect) in these approaches could improve considerably.

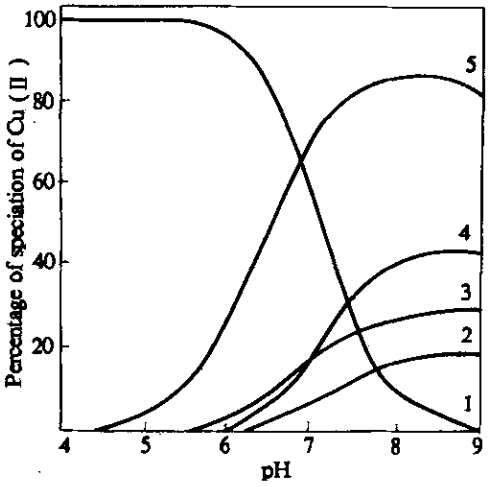

Fig. 6 Changes of pH in chemical experimental enclosure ecosystem bags

Transparency is an important parameter of eutrophication. Because of the flocculation of Al^{3+} and Fe^{3+}, suspended substances in lake water can be precipitated. Moreover, some

Table 7 Soluble P in enclosure ecosystem bags treated with chemicals

Approach	SRP, mg/L	Percentage of SRP to control, %
2 mg Cu/L	0.048	109
1 mg Cu/L, 15 mg Fe/L	0.011	25
7.5 mg Fe/L, 3.5 mg Al/L	0.013	30
20 mg Fe/L	0.011	25
Control	0.044	100

precipitation could enter into the colony of *Microcystis*. The increase of weight causes the *Microcystis* colony being inlaid with particulate matter can be observed through a microscope. Fig. 7 shows the change of transparence as a result of treatment with iron and aluminum salts.

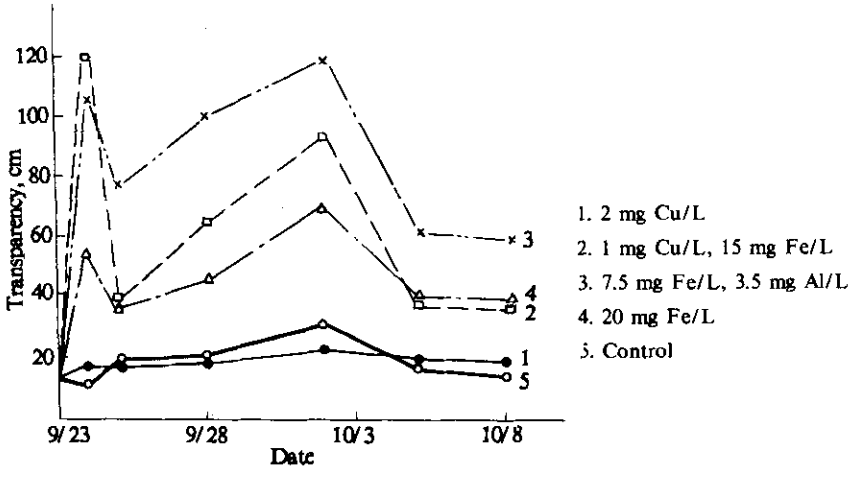

Fig. 7 Changes of water transparency in enclosure ecosystem bags treated with chemicals

3. Fe^{3+} and Al^{3+} react with phosphate and cause precipitate. The resulting concentration in different approaches are shown in Table 7. The difference on soluble reactive phosphorus concentration (SRP) in Talbe 7 is very remarkable.

CONCLUSIONS

1. The enclosure ecosystem bags closely simulate the natural lake environment. Moreover, some chemical and environmental factors can be regulated in the bags. This lays a good foundation for the study of the control of algal blooms in lakes.

2. As synergists, Fe^{3+} and Al^{3+} can greatly enhance the effect of algicides, and they are also better inhibitors of the development of *Microcystis* blooms.

3. *Salvinia* is also a good inhibitor.

4. 0.20 – 0.30 mg/L Cu^{2+} can effectively control the development of a *Microcystis* bloom.

5. 0.019 mg/L ortho-phosphate is regarded as a threshold which affects the development of *Microcystis* blooms.

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