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The Micro Ecosystem Restoration Mechanism Applied for Feasible Research of Lakes Eutrophication Enhancement

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***Abstract*—**The technique of inducing micro ecosystem restoration is one of aquatic ecology engineering methods used to retrieve the polluted water. Batch scale study, pilot plant study, and field study were carried out to observe the eutrophication using the Inducing Ecology Restorative Symbiosis Agent (IERSA) consisting mainly degraded products by using lactobacillus, saccharomycete, and phycomycete. The results obtained from the experiments of the batch scale and pilot plant study allowed us to development the parameters for the field study. A pond, 5 m to the outlet of a lake, with an area of 500 m^2 and depth of 0.6-1.2 m containing about 500 tons of water was selected as a model. After the treatment with 10 mg IERSA/L water twice a week for 70 days, the micro restoration mechanisms consisted of three stages (i.e., restoration, impact maintenance, and ecology recovery experiment after impact). The COD, TN, TKN, and chlorophyll a were reduced significantly in the first week. Although the unexpected heavy rain and contaminate from sewage system might slow the ecology restoration. However, the self-cleaning function continued and the chlorophyll a reduced for 50% in one month. In the 4th week, amoeba, paramecium, rotifer, and red wriggle worm reappeared, and the number of fish flies appeared up to1000 fish fries/m^3. Those results proved that inducing restorative mechanism can be applied to improve the eutrophication and to control the growth of algae in the lakes by gaining the self-cleaning through inducing and competition of microbes. The situation for growth of fishes also can reach an excellent result due to the improvement of water quality.

***Keywords*—**Ecosystem restoration, eutrophication, lake.

I. Introduction

INDUCING micro ecosystem restoration is one of aquatic ecology engineering methods by using a restorative symbiosis agent. In 1989, Mitsch [1] first proposed the concept of ecological engineering and emphasized symbiosis through the interaction between artificial environment and natural environment based on self-design's ability of the system.

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Brook and Shield [2] established the spirit of ecological engineering for restoration, rehabilitation, enhancement, creation in 1996 and Vannote [3] also brought up the naturalization method, and restoration definition. The restoration concept and methods were developed for the process of river's self-cleaning in "biology of wastewater treatment" [4] and "rehabilitation of river" [5] included soil–based or land–treatment systems (e.g., slow rate, rapid infiltration, overland flow), aquatic–based systems (e.g., constructed or natural wetland), and aquatic plant treatment systems. The probiotics microbes instead of antibiotics were applied in food industry for fish farming [6]-[7]. So far, based on our knowledge no related application in lakes rebuilding has been reported because of failure to due to induce restoration of microbes original by mean of use of probiotics as a mainly living creature agents. Application of microbe ecosystem restoration to establish the microbes system could be an important milestone in developing biological technique for ecological construction.

The process of micro ecosystem restoration, utilization of the ecological environment nature under inducing the micro ecological control procedure, is developed in the present research instead of the traditional methods. The property ratio of nutriment and enzymes of microbes were induced into an ecological environment. The ecological system was established under the biological competition natural selection for the growth of microbes that can induce the original ecological environment, and accelerate the development of the complete ecological food chain. The eutrophication of single species in the monotonous water can be converted to a multiple balanced and stable ecological systems. Due to micro ecosystem restoration agents contained the abundant nutrient and enzymes, the secondary creature can grow sturdy. The groups of third or higher creatures also are also able to gain more survival opportunity. As a result, a healthful and stable food chain is expected to establish gradually, and the ecological environment returns to be normal. Furthermore, an aquatic body is able to undergo the self-cleaning function. The purpose of this research is to verify the efficiency of starting the restoration mechanism in eutrophication lakes, and to understand the feasibility of lakes eutrophication's improvement by this restoration processes.

II. Materials and Methods

A. Preparation of Micro Ecological Restorative Agents

The process to cultivate the agent for a food chain in this study by using three species of bacteria, i.e., lactobacillus, saccharomycete, and phycomycete, under a specific condition to mutualism has been developed in our laboratory for more than 20 years. The cultivated resultant was obtained as a solid from the mixture of rice planting, pasturage, and marine products, in which the quantity of germ is approximately of 10^7-10^8/g. In 1992, the mixture of these three germs used in a specific drive system had been studied. Those germs were later applied as a special ecological germ group for the pollution treatment, such as waste water treatment with germ quantity of 10^6/g. However, these agents caused the competition with original microbes and became to the barrier for the growth of original creature until the nutrient is vanished. A continuously inducing ecosystem restorative symbiosis agent (IERSA) was thus developed in 2001 by using lactobacillus as an inducing center, with the participation of local microbes to generate the sufficient nutrition. The agent consisting of the germ amount of 10^4~10^5/g was processed with low-temperature sterilization and vacuum package.

B. Batch Scale Study

An 8 L aquarium in the size of 15 cm × 20 cm × 25 cm and a 4 feet (250 L) aquarium in the size of 4' × 2' × 3' (depth 2') were designed to circulate the eutrophication lake water at the flow rate of 60 L/min. After the ecology agent had applied for 6 days, the fishes were cultivated for evaluating the quality of the water. The doses of 10 mg agent/L water were added three times during the periods of nine days.

C. Pilot Plant Study

A 15 tons aquarium, in the size of 15 m × 1.5 m × 0.7 m was used for the test. The water in the aquarium was circulated by sucking the eutrophication lake water at flow rate of 60 L/min. The water samples were collected on day one, 10th day and 18th day after applying the agent. The doses of 10 mg agent/L water were added three times during the periods of nine days.

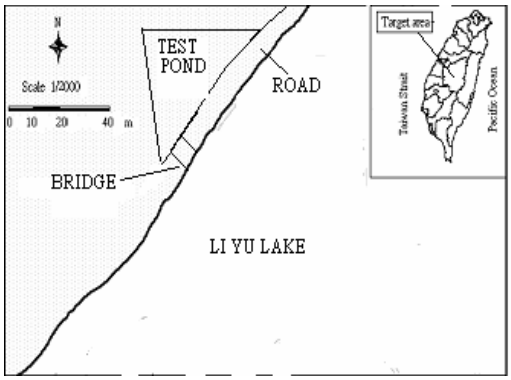

Fig. 1 Location of test pond

D. Field Study

This field study was conducted at the Li Yu Lake (18 hectare area), Nan Tou county in central Taiwan in 2008 (see Fig. 1). The test pond only is just 5 m away from the lake with connecting of a canal. Jin [8] used Wuli Lake at the outlet of Tai Lake in China as the test ponds. The water quality in Li Yu test pond was comparable with that in Wuli Lake, except for that higher chemical oxygen demand and chlorophyll-a [8] in the former (see Table I).

The test pond is an open environmental system. Ground water and rain are the main source of water in the Li Yu Lake. A waste-water treatment plant, located near the test pond, discharges about 20 CMD of water into the test pond from the plant. In additional to that, this test pond also receives the untreated waste water discharge from residential area.

The present study started on March 16, 2008 for 75 days; the agent was used in the first month, twice per week, for the experiment of restoration. The agent was added at same dose for every 10 days consecutive weeks in second month (from Apr 14 to May 11) for ecological maintenance due to moonshine season. The ecological recovery experiment was performed in the third month (from May 11 to June 1) with same dose of agent twice per week.

E. Analysis of Water Quality Sample

To evaluate the variation of quality of the water, the samples were collected from 5 points (B、C、M1、M2 and M3 as shown in Fig. 2) on the first day of every week. A 5 HP submergible pump was used to circulate the water in the test pond to obtain a better homogeneity of water quality.

The parameters were analyzed for each sample included: water transparency, temperature, pH value, COD, BOD, total solid, chlorophyll a, total phosphorus (TP), ammonia nitrogen (ammonia-N), nitrate nitrogen (nitrate-N), and total Kjeldahl nitrogen (TKN). Standard Methods were followed for those examinations. Temperature, pH, DO, electrical conductivity, ORP and TDS were measured on-site.

F. Photoplankton and Zooplankton Counting Techniques

The Standard Method [9] for analysis of zooplankton and microscopes were adapted for analysis of the samples. An Olympus headstand microscope was used for observation, and Olympus camera was used for making the photograph. For the microscope observation the objective glass was set for 4x, 10x, 40x and the eyepiece 10x, with the largest magnification of 3.5x. A 0.01 mL micro dropper was used to sample the water for observing and photographing the biological flocculation.

G. Fish Counting Techniques

The Standard Method [10] were followed to collected fish at five sampling points by using a fishing net, diameter 30 cm x 30 cm (high), and three samples were collected at each point.

III. Results

A. Observation of Aquarium-Batch Scale Study

In the batch scale study, the eutrophication sample (chlorophyll a 108 μg/L) was added into the aquarium (250 L), in which the alga was the only one superior creature in the beginning. *Mastigophora*, amoeba, etc. were detected three days after adding micro ecological restorative agent, and a large amount of paramecium and few vorticella were also detected on 4th day. At the same time, the algae started to collapse to produce the filamentous bacteria, followed by biological flocculation formation and creatures silt produced. On the 5th day, bdelloid rotifers appeared gradually in the silt. On the 8th day, philodina was found and a gold fish was introduced in. Red wriggle worms appeared on the 10th day, which were eaten by the gold fish (see Fig. 2 and Fig. 3).

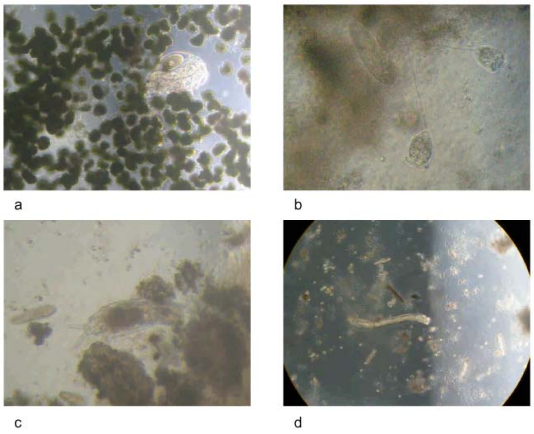

Fig. 2 (a) Only blue-green algae found, (b) *Vorticella* and *Colpidium*, (c) rotifers, (d) chironomidae

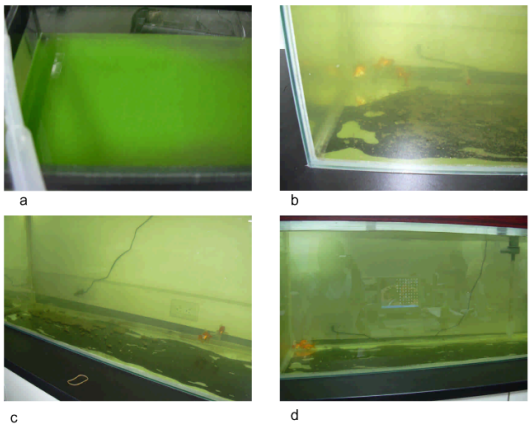

Fig. 3 (a) The aquarium water was occupied by the blue-green algae, (b) the algae started collapsing with formation of filamentous bacteria, biological flocculation, and biological silt, (c) put gold fish in, (d) gold fish ate all the worms

B. Pilot Plant Study

The micro ecology observed in the 15-tons aquarium was similar to that in the batch scale stud during the 20 day observation, and all worms were eaten by the gold fish. Table II shows the change of water quality during the pilot study. BOD, COD, TN, TKN, and chlorophyll-a were reduced significantly, but total phosphor, NH_3-N、NO_2-N、NO_3-N increased obviously. The self-cleaning process was executing during the 18 days test after introducing the micro ecological restorative agent.

TABLE II
THE EXAMINATION RESULT OF PILOT PLANT STUDY AFTER ADDING IERSA

Date	2006/5/12	2006/5/22	2006/5/31
	Day 1	10th day	18th day
Water temperature, °C	23.5±0.00	22.00±0.00	27.9±0.041
pH	8.8 ±0.00	7.9 ±0.00	7.35 ±0.041
Total solid, mg/L	153.5 ± 20.0	97 ± 3.27	104 ± 0.816
COD, mg/L	97.25 ± 18.58	16.9 ± 0.16	22.65 ±1.51
BOD, mg/L	32.85 ±3.06	4.9± 0.73	5.3 ± 0.082
Total phosphorus, mg/L	0.19±0.08	0.10±0.02	0.378±0.00
TKN, mg/L	2.34 ±0.05	0.82 ±0.05	0.99 ± 0.02
Ammonia-N, mg/L	0.10 ± 0.02	0.17 ±0.01	0.325 ±0.02
Organic-N, mg/L	2.25 ± 0.03	0.65 ± 0.04	0.67 ±0.00
Nitrate-N, mg/L	ND	ND	0.14 ±0.028
Nitrite-N, mg/L	<0.01	<0.01	0.027±0.005
Total nitrogen, mgL	2.34 ±0.05	0.82 ±0.05	1.15±0.008
Chlorophyll a, μg/L	158.5 ± 41.3	9.4 ± 0.41	1.9 ± 1.47

C. Field Study

The water from people activities and treatment plant are estimated to discharge 5.8 g/day of COD and 0.63 g/day of NH_3-N, 0.07 g/day of TP into the test pond. High concentration of blue-green algae and chlorophyll-a (136.00 μg) resulted in poor water transparency (20.2 cm) and critical condition for the fish survival. After one month (from Mar 16 to Apr 13) of micro ecological restoration, COD, TN, TKN and chlorophyll a were significantly reduced (Table III). The rainfall and discharge from waste water treatment plant delay the ecological restoration mechanism, and the self-cleaning appeared until March 30. Although no significant variations in the levels of BOD, COD, TN, and TKN were observed during the raining period, but chlorophyll a concentration reduced obviously. No odor and silt smell was detected from the water as well; the restoration of amoeba, paramecium, and rotifers started on the 3rd and 4th weeks. Red wriggle worms and fish fries were observed. By the end of month, approximately 1000 fish flies/ m^3 were recorded. After a heavy rain (51 mm/day) on April 21, a one-month maintenance experiment started. During the heavy rain, a large amount of water overflows from the Lu Yu Lake into test pond. On May 11, the water quality in the test pond was deteriorated and only few active creatures were observed. After additional week's restoration, all of the water quality parameters were improved to the status of April 13, and small fishes in the lengths of 1-2 cm were observed with the presence of amoeba and rotifers again.

TABLE I
COMPARE THE WATER QUALITY OF WULI LAKE AND TEST POND

Indicator Unit Value	Wuli Lake,			Test Pond		
Area, m^2	5,150,000			500		
Deep, m	3.24 (2.81, 4.28)			1.1 (0.7, 1.8)		
Water temperature, ^oC	18.30 ± 8.91			24.01±1.96		
Water transparency, cm	35.15 ± 8.19			30.2 ±4.44		
pH	8.16 ± 0.45			9.13 ± 0.13		
Electrical conductivity, μs/cm	53.36 ± 7.38			56.05 ± 12.97		
Total phosphorus, mg/L	0.17 ± 0.052			0.13 ± 0.06		
Total nitrogen, mg/L	7.63 ± 2.11			4.71±1.05		
Dissolved oxygen, mg/L	7.48 ± 3.08			7.96 ± 1.79		
Chemical oxygen demand, mg/L	7.11 ± 2.26			37.52 ± 4.87		
Ammonia-nitrogen, mg/L	4.43 ± 1.76			1.28 ± 0.24		
Chlorophyll-a, μg/L	76.66 ± 35.90			136.00 ±27.51		
Water quality level [8]	V					
Trophic status [8]	eutrophic			eutrophic		
Pollution source	COD (g/day)/m^3	T-P(g/day)/m^3	T-N(g/day)/m^3	COD(g/day)/m^3	T-P(g/day)m^3	T-N(g/day)m^3
Industrial waste water	0.170	0.001	0.013	-	-	-
Domestic waste water	0.973	0.011	0.108	4	0.03	053
Restaurant pollution	0.075	0.002	0.019	1.8	0.04	0.12
Non-point source						
Pollution	0.095	0.002	0.019			
Aquaculture	0.655	0.006	0.078			
Precipitation	0.093	0.001	0.014			
Shipping	0.013	0.000	0.003			
Total	2.074	0.022	0.254	5.6	0.07	0.65

TABLE III
WATER QUALITY OF THE TEST POND AFTER RESTORATION

	Test pond							control	
Area, m^2	500							180000	
Date	2008/3/16	2008/3/23	2008/3/30	2008/4/6	2008/4/13	2008/5/11	2008/5/181	2008/3/16	2008/5/11
Precipitation, mm/wk		3	27.5	67	28.5	209[(a)] mm/month	0		
Deep, m	1.1(0.7,1.8)	1.1(0.7,1.8)	1.1(0.7,1.8)	1.1(0.7,1.8)	1.1(0.7,1.8)	1.3(0.9,2.0)	1.3(0.9,2.0)	1.8(0.9,2.6)	1.8(0.9,2.6)
Water temperature, ^oC	24.01±1.96	23.55±0.18	23.21±0.20	24.39±0.17	26.71±0.33	29.65±0.07	26.6±0.26	24.6±0.98	29.5±0.57
Water transparency, cm	20.2 ±4.44	34.1 ±4.02	41.8 ±2.64	50.2 ±2.93	55.4 ±3.93	40.2 ±4.44	48.8 ±2.74	30.4 ±5.12	35±6.44
pH	8.97 ± 0.13	6.93 ± 0.14	6.93 ± 0.14	6.99 ± 0.12	7.2 ± 0.08	9.07 ± 0.17	7.28± 0.17	8.78±0.74	9.13 ± 0.76
Conductivity, μs/cm	66.05 ± 2.97	53.13 ±2.13	104.4 ±1.74	69.53 ±5.26	69.33 ±2.33	52.87±0.81	39.2±1.01	67.8±2.93	52.5±0.95
TP, mg/L	0.13 ± 0.06	0.24 ± 0.05	0.27 ± 0.03	0.32 ± 0.08	0.38 ± 0.09	0.19 ± 0.07	0.22 ± 0.02	0.13 ± 0.08	0.12 ± 0.06
TN, mg/L	4.71±1.05	3.2±0.85	4.42±0.54	2.74±0.45	3.14±0.56	4.40±0.71	3.36±0.34	1.9±1.03	3.91±1.01
DO, mg/L	9.67 ± 1.79	2.13 ± 1.25	3.39 ± 0.15	4.61 ± 1.14	4.57 ± 0.51	9.68 ± 0.51	1.25 ± 0.98	8.89±0.70	9.43±0.87
COD, mg/L	37.52 ± 4.87	32.8 ±2.76	27.0 ±3.19	36.0 ±8.79	36.2 ±1.60	67.0 ±12.98	79.2 ±5.07	52 ±5.03	62.0 ±9.81
Ammonia-N, mg/L	1.28 ± 0.24	1.1 ± 0.18	1.73± 0.13	1.84± 0.17	1.36± 0.29	1.01± 0.42	0.41± 0.06	0.11± 0.03	1.15± 0.48
Chlorophyll a ug/L	136.0 ±27.5	75.7 ±10.57	97.9 ±4.05	86.9 ±4.61	65.9 ±6.61	141.0 ±27.7	55 ±9.47	120.0 ±18.6	127.0±24.76
odor	+++	+	-	-	-	-	-	++	++
Vorticella	-	+	+	±	±	±	±	-	-
Arcella	-	-	+	+	++	-	++	-	-
Phlodina	-	-	+	+	++	-	++	-	-
Chiroromus	-	-	+	+	+	-	+	-	-
fish(< 5mm)	-	-	+	++	+++	+	++	-	-
fish(10mm-20mm)	-	-	-	-	-	+	++	-	-
fish(20mm以上)	-	-	-	-	-	-	++	-	-
fish(100mm以上)	-	-	+	+	+	+	+	±	±

Zooplankton in sludge (- 0/mL, + 10/mL, ++100/mL)
Fish (- 0/m^3 , + 10/m^3, ++100/m^3, +++1000/m^3)
(a) Apr 21, 55 mm rain fall per day

D. The Relationship between Total Phosphorous and Chlorophyll A

Wang [11] has conducted a large-scale investigation on phytoplankton biomass (measured as chlorophyll-a) from 45 shallow lakes along the mid-lower Yangtze River in China to verify the hypotheses concerning nutrient limitation. Wang pointed out that TP is a primary regulating factor of chlorophyll a. Our study also showed that phosphorous was main growth factor for the algae, when no restoration agent was added into the aquarium, the correlation appeared as Y=1.76+0.18X, R=0.82 [while Y: Chlorophyll a log (mg/m^3), X: TP log (mg/m^3)](see Fig. 4). But the surviving space of algae was instead of other microbes after adding ecological restorative agent, the presence of phosphorous doesn't influence on the growth of algae. There was a negative relationship between phosphorous and chlorophyll a when the IERSA was added into the aquariums.[Y=3.5-0.34X, R=-0.6 (in a batch scale study), Y=4.1-1.3X, R=-0.47 (in Pilot plant study), Y=2.51-0.22X, R=-0.43(in a field study)].

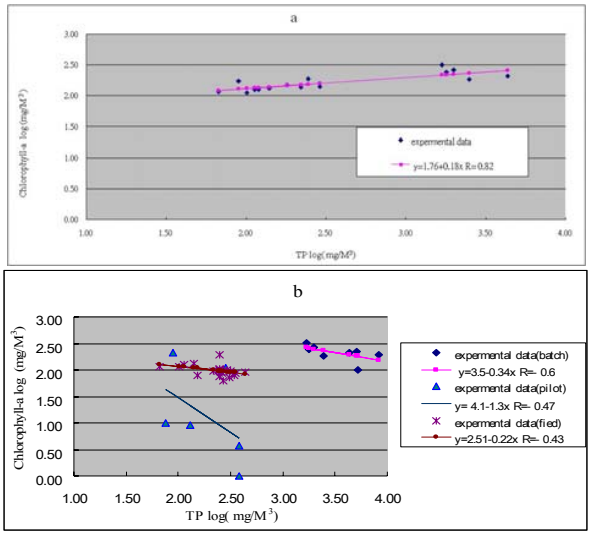

Fig. 4 Correlation between total phosphorous levels and chlorophyll-a concentration (a) without adding ecological restorative agent, (b) with adding the ecological restorative agent

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IV. CONCLUSION

The present study shows that restoration mechanism can improve the eutrophication in the lake in among batch scale study, pilot plant study, and field study. A significant improvement can be observed within 15-30 days. In which the rotifers appeared within 20 days, and self-cleaning eutrophication can be reached with the competition of microbes, and the algae also being well controlled. Fish cultivation becomes possible due to water quality improvement. Since the local microbes are required for the preparation of this micro ecological restorative agent, therefore, the on-site preparation of this agent is recommended.

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