Engineering Research of the Microbial Revitalization of Xiba River with Microbe-Lift® Technology

Location: **Kunming City, Yunnan Province, China**

Study conducted by Prof. Hu Kailin, Deng Liu, Wang Lifeng, Dang Yan, Chen Yusong, Han Bing and Wang Hao (Faculty of Environmental Science & Engineering, Kunming University of Science and Technology, Kunming) Project Advisor: Goh Kwang Beng. Project Period: 21 Nov 2004 to 22 April 2005.

Introduction:

"More than US$ 2 billion have been spent from 1993 to 2000 to clean up the Dianchi Lake in China's scenic Yunnan province. But the investments have produced little if any payoff because they have not addressed the root sources of pollution such as agricultural runoff. The central and provincial governments are now looking for innovative ways to address the problem." Quoted from an online April 2000 report by the U.S. Embassy Beijing.

According to a 1998 report by the State Environmental Protection Administration (SEPA), 185 million cubic meters of liquid waste were dumped into the Dianchi Lake in 1995, of which roughly 50 million cubic meters were industrial wastewater and 135 million cubic meters were domestic sewage. Pollution levels in the upper Dianchi Lake still regularly exceed the worst level (Five) on China's five-level water quality scale. Level-Five is defined as being suitable for agricultural use but not appropriate for swimming or for fishing. Water quality is somewhat better in the southern part of the Lake, usually measured at level-three (acceptable for swimming and fishing) or level-four (suitable for industrial and non-swimming recreational use) standards. The current target is to improve water quality throughout the lake to a minimum level-four standard by 2010.

The cleanup measures to date have failed to stem the pollution because they have focused almost exclusively on point sources around the lake's periphery. They have not addressed agricultural runoff or pollution of the Lake's tributaries. According to a recent press report, 80 percent of domestic sewage entering the 16 rivers that flow into the Dianchi Lake remain untreated. Meanwhile, heavy use of chemical fertilizers and pesticides on farm fields lying east of the Lake leads to extremely high runoff of nitrates and phosphates. According to the 1998 SEPA report, 1,021 metric tons of phosphorous and 8,981 tons of nitrogen entered the Lake in 1995. The Dianchi Lake Management committee is fully aware that the main cause of water pollution is water flowing into Dianchi from its 16 tributaries.

Ecological Laboratories authorized representatives from the United States presented a program for biological remediation of Dianchi Lake using Ecological's unique bacteriological based products in March 2004. The small, but badly polluted river was offered to Oakwell Engineering as a trial project using products formulated with Ecological's MICROBE-LIFT® proprietary technology. The Xiba River flows into the most polluted Northern part of Dianchi Lake, and was deemed to be good, but challenging test of open water bioremediation. Kunming

University of Science & Technology was engaged as an independent research party to conduct the trial, and working as the local administrator for the project.

A preliminary laboratory test on the effectiveness of Ecological Laboratories products in treating the polluted water and sludge in Xiba River was conducted at the University in May 2004 with satisfactory results. However, the actual trial project was postponed to 21 November 2004 to avoid the rainy season in July and August. The project was carried out from 21 Nov 2004 to 22 April 2005.

Objective of the Xiba River Trial:

Formulations developed, manufactured and packaged by Ecological Laboratories were proposed as a bioremediation product for the Dianchi Lake rehabilitation in March 2004. The Dianchi Management Committee offered Xiba River to Oakwell Engineering Limited to conduct a trial testing the effectiveness of these products in treating polluted water in the Dianchi Lake. The river is a small, slow flowing tributary with extremely polluted water emanating a bad odor. The trial project was conducted to determine the effectiveness of this unique and novel biological treatment plan to eliminate odor, improve water quality and to accelerate river rehabilitation to reinstate higher forms of living organisms in the river.

What is MICROBE-LIFT® Technology?

MICROBE-LIFT® products are highly active liquid bacteriological consortiums designed specifically for use in polluted lagoons, lakes, rivers, industrial and municipal wastewater systems. This "core technology" contains a diverse blend of selected microorganisms with a specification of 387/450 million microorganisms/ml. The product, through Bio-augmentation, accelerates the biological oxidation of slow to degrade organic matter utilizing a broad spectrum of aerobic, anaerobic, facultative, chemo- and photo-synthetic bacteria.

Products manufactured with MICROBE-LIFT® formulas by **Ecological Laboratories** are very effective....
In enhancing the biological oxidation of the slow to degrade organic compounds various types of wastewater systems, as well as open water ponds, lakes, lagoons, and rivers. Treatment results have significantly improved overall system performance and environmental health and stability.

By increasing overall microbial oxidation rates, significantly increasing organic degradation performance. This unique microbial consortium provides reductions in final effluent BOD, COD, TSS, turbidity and improves effluent discharge into the rivers, lakes or sea, while reducing waste sludge volume that has been built up in the river bed over time.
The Xiba River has very high nitrogen and phosphorus content that supports eutrophication, which in turn causes serious green water events problems in the lake. Bioremediation is the most cost effective means in reducing eutrophication and improving water quality in the river.

About Xiba River

The Xiba River is 4km long, with a width range from 4 to 9m, and a depth ranging from 0.5 to 1.0m. The average flow rate is 0.3 m^3/s (26,000 m^3 per day). The water is badly polluted and has a grayish color most of the time. It emanates bad odors, particularly during the dry months from April to August, that can be detected as far as 20m from the river bank.

The pollutants are mostly from illegal dumping of direct domestic sewer discharge, agricultural and animal farm wastewater, slaughter house wastewater as well as small industrial waste, including waste from cement plants. River flow can be extremely high during illegal discharge, occasionally completely upsetting trial results. The trial was conducted in the last 1.5 km before the river mouth at Dianchi Lake.

Figure 2: *Condition of Xiba River before Trial Treatment on 21st November 2004*

Procedure of the Xiba River Trial.

The trial was conducted on the last segment of Xiba River on a stretch ranging 1,460m to 300m from Dianchi Lake. The segment from 750m to 1,260m was installed with our uniquely designed biomedia to increase the bacteria resident count. Fig 3 shows the dosing and water sampling locations. Dosing is applied daily based on water flow volume at approximately 1 ppm per day. The MICROBE-LIFT® formulation was poured directly into the designated dosing location. Water samples were taken from the river with a plastic cup with an extended arm scooping water from the river center at the sampling point.

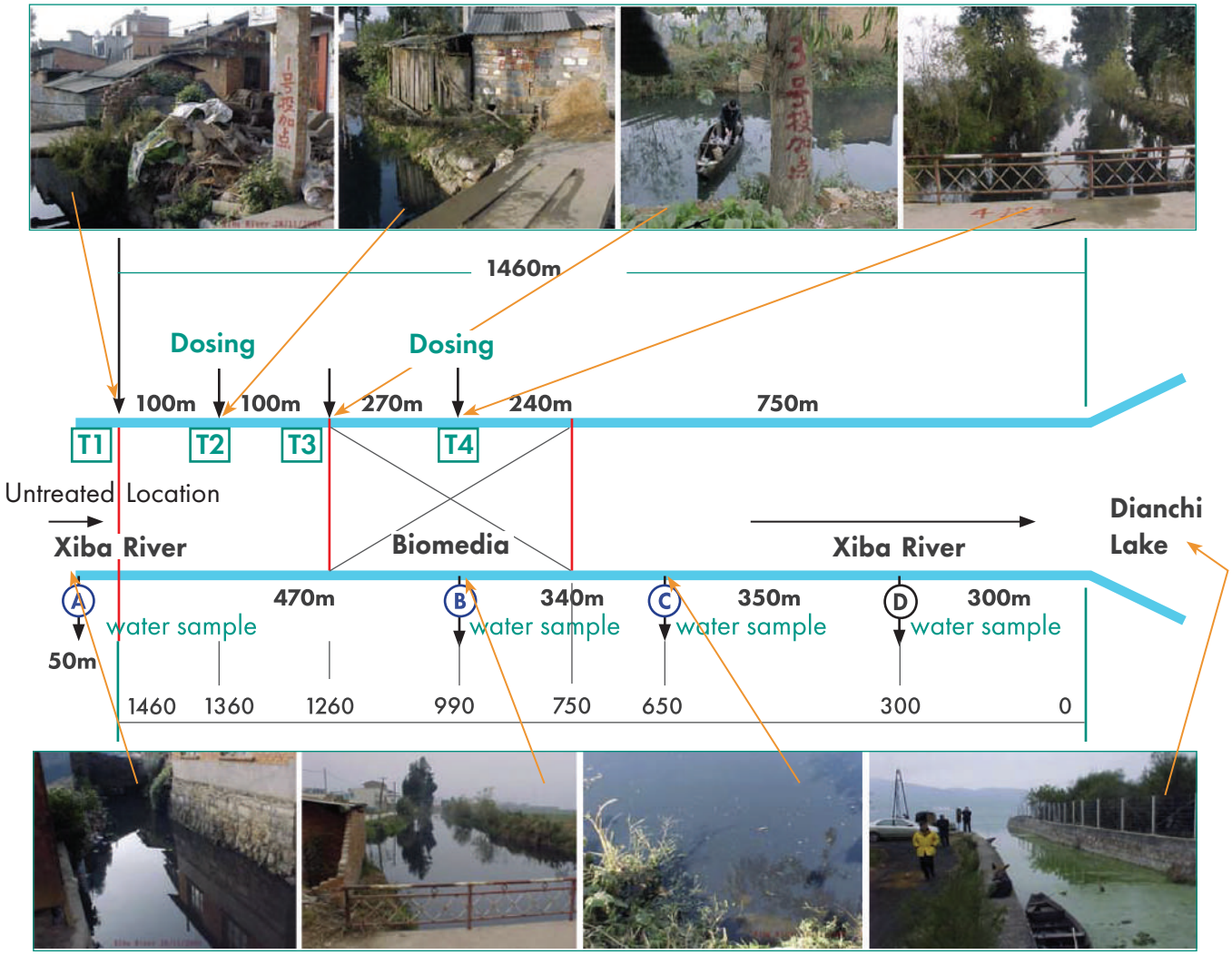


Fig 3: *Dosing and water sampling location of the Xiba River trial*

The water parameters that were monitored were BOD5, CODcr, Total Nitrogen, Total Phosphorus, Turbidity, TSS and pH on a weekly basis. Appendix 1 tabulates the dosing volume, water parameter measurement record and weather record during the trial period.

Table1 shows the water parameters before treatment at the beginning of the trial. The ultimate desired standard of the authorities is Level-Three, as indicated in the last column of the table for reference.

Parameter	Before Treament April 5, 2004	Start of Treatment November 21, 2004	Level III Standard
COD (mg/l)	176	56.20	20
BOD (mg/l)	64.4	31.8	4
TSS (mg/l)	63	8.0	
TN (mg/l)	28.1	11.04	1.0
TP (mg/l)	2.58	1.0	0.1
Turbidity	130	39.8	
pH	7.29	7.0	6 - 9

Table 1. *Existing Water Parameter vs Level III standard*

Dosing Computation

A river is a continuous dynamic system with great variations in flow from time to time. It is not possible to accurately compute the water volume and retention time in the trial zone. We have computed the dosing based on the assumption that river flow is relatively low as has been noted at the site most of the time. The trial zone was designated from the 300m from the mouth of the Dianchi Lake upstream 1,460m, for a total treatment zone of 1,160m in length. The average width and depth at this section of the river is 6.0m and 0.9m respectively. This gives a total volume of 7,884 m3. The normal flow rate without major dumping or rain is 0.3 m3/s. This gives an average retention time of 7.3 hours. That means the water takes approximately 7.3 hours from the beginning of the test zone at D1 to the end of test zone at T4. Since the retention time is less than 24 hours in the test zone, dosing is computed based on daily flow rate as per manufacturer's recommendation.

Based on a 0.3 m3/s flow rate, daily volume of water flow is 26,000 m3 (6.8 million gallons). At 10 ppm inoculation, 68 gallons will be needed. At the time of project evaluation, the estimated flow was based on 3.2 million gallons per day as detected earlier. The inoculation was hence carried out with 32 gallons on 21 Nov 2004. The flow rate was subsequently detected at 6.8 million gallons per day, it was then recommended to maintain 4.7 ppm of daily flow rate per week for the next four weeks. Regular large volumes of untreated wastewater were found to have been dumped into the river, thus upsetting the water volume computation and trial progress.

It was decided that the dosing be converted to 6 gallons (0.88 ppm per day based on daily flow volume) dosed on a daily basis from 13 Dec 2004 onwards. There were some minor changes to actual dosing depending on site condition and progress. In general, the daily dosing was divided into 4 portions with 65% dosing at dosing point C just before the start of biomedia. Very low dosage was applied at dosing point A and B because the river at this section is very narrow and has a low water volume. 15% of the estimated dosing was applied at dosing point D at the middle of the biomedia section to ensure that is sufficient bacteria to flow to the last section of the trial. With a flowing river of this nature, a single point dosing is sufficient as experienced in this trial.

Water Quality Monitoring and Result Evaluation

Water samples from four locations as indicated in Fig 3 namely T1, T2, T3 and T4 were taken on a weekly basis for water parameter monitoring. T1 is located 90m before the first dosing point upstream. The water parameter at T1 represents pre-treatment water sample. T2 is located at the middle of the biomedia zone. The water here is subject to 2 to 3 hours of treatment as it flows from T1 to T2. T3 located further downstream, 650m from Dianchi Lake. The water at T3 has gone through approximately 5 hours of treatment under normal flow. T4 is the last water sample point at 300m before Dianchi Lake. The water at T4 has been treated for approximately 7 hours under normal flow rate.

The water parameter varies from day to day as upstream discharge changes. The water quality downstream is therefore greatly influenced by upstream water parameters, i.e. influent quality at T1. It is therefore meaningless to track the water quality over time like in a lagoon system. Our objective then is to track the improvement of water quality from T1 to T4 on the day of measurement.

The commencement of the trial period coincided with a very unfavorable period of cold temperature. Although Kunming City has the reputation of a city with eternal spring, there were two periods with sub-zero temperatures and snow which severely affected the effectiveness of MICROBE-LIFT®. The period from November to March falls in the dry season, however there were a few instances of heavy rainfall in addition to low temperatures during the trial period that changed the river water completely on 29th Nov 2004, 18th Dec 2004, 12th Jan 2005 and 23rd March 2005. Besides the weather factors, the regular dumping of huge volumes of untreated polluted water upset the trial further. This is reflected on 6th March and 27th March 2005. The water quality improved significantly from T1 to T4 from Feb 6th to Feb. 27th Feb 2005. However, the improvement was severely interrupted by further dumping of a huge volume of untreated agricultural wastewater on Feb 28th 2005.

Following the dumping on 28th Feb, there was unexpected snowfall on 3rd and 4th of March with temperatures ranging from -1 to 10°C. Dosing was called off on the 4th and 5th of March 2005 and resumed on the 6th of March. Despite the interruption, the trial zone recovered its earlier ecological balance within two weeks from 6th March as seen on 20th March 2005. The ecological balance this time round was, however, upset by a huge volume of very alkaline wastewater dumped by a cement factory upstream. The river was completely covered with milky water on 23rd March 2005. The dosing ended on 29th March 2005 due to a delay in new shipment. Dosing resumed on 10th April 2005. However, the trial continued to be interrupted by blatant dumping of huge volumes of untreated wastewater. The trial ended on 22nd April 2005.

Xiba River Project

Selective Result Presentation.

T1 Untreated water Sample
T2 2nd water Sample at Biomedia Zone
T3 3rd water Sample 650 m from Dianchi Lake
T4 4th water Sample at 300 m from Dianchi Lake

BOD5 mg/l

Date	T1	T2	T3	T4	Remarks
11/21/2004	31.80	31.90	27.60	28.30	Inoculation
12/19/2004	38.80	41.50	38.30	41.90	Not much change noted
02/06/2005	14.30	12.50	7.07	7.67	about 50% improvement at T3 and T4
02/27/2005	20.90	30.60	13.00	8.81	About 60% improvement
03/06/2005	21.10	23.00	26.00	30.30	Affected by dumping and snow
03/20/2005	45.00	24.00	20.10	21.40	System recovered within two weeks
03/27/2005	30.40	38.80	31.60	26.20	Affected by cement factory waste

CODcr mg/l

Date	T1	T2	T3	T4	Remarks
11/21/2004	56.20	64.30	60.20	76.30	Inoculation
12/19/2004	90.00	88.00	92.40	94.00	Not much change noted
02/06/2005	100.00	76.00	58.00	52.00	about 50% improvement at T3 and T4
02/27/2005	53.35	71.14	43.47	39.52	about 25% improvement
03/06/2005	90.90	86.94	82.99	81.02	Affected by dumping and snow
03/20/2005	130.42	94.85	75.09	67.18	System recovered within two weeks
03/27/2005	88.92	90.90	86.94	81.02	Affected by cement factory waste

TSS mg/l

Date	T1	T2	T3	T4	Remarks
11/21/2004	8.00	5.50	4.50	2.50	Inoculation
12/19/2004	9.50	8.00	9.00	11.00	Not much change noted
02/06/2005	3.50	7.50	3.00	5.50	increase at T4, reason unknown
02/27/2005	23.00	8.50	4.00	6.00	80% improvement
03/06/2005	9.00	10.00	8.50	24.00	Affected by dumping and snow
03/20/2005	8.50	4.00	3.00	0.50	System recovered within two weeks
03/27/2005	3.00	4.00	2.00	1.50	Affected by cement factory waste

Turbidity (NTU)

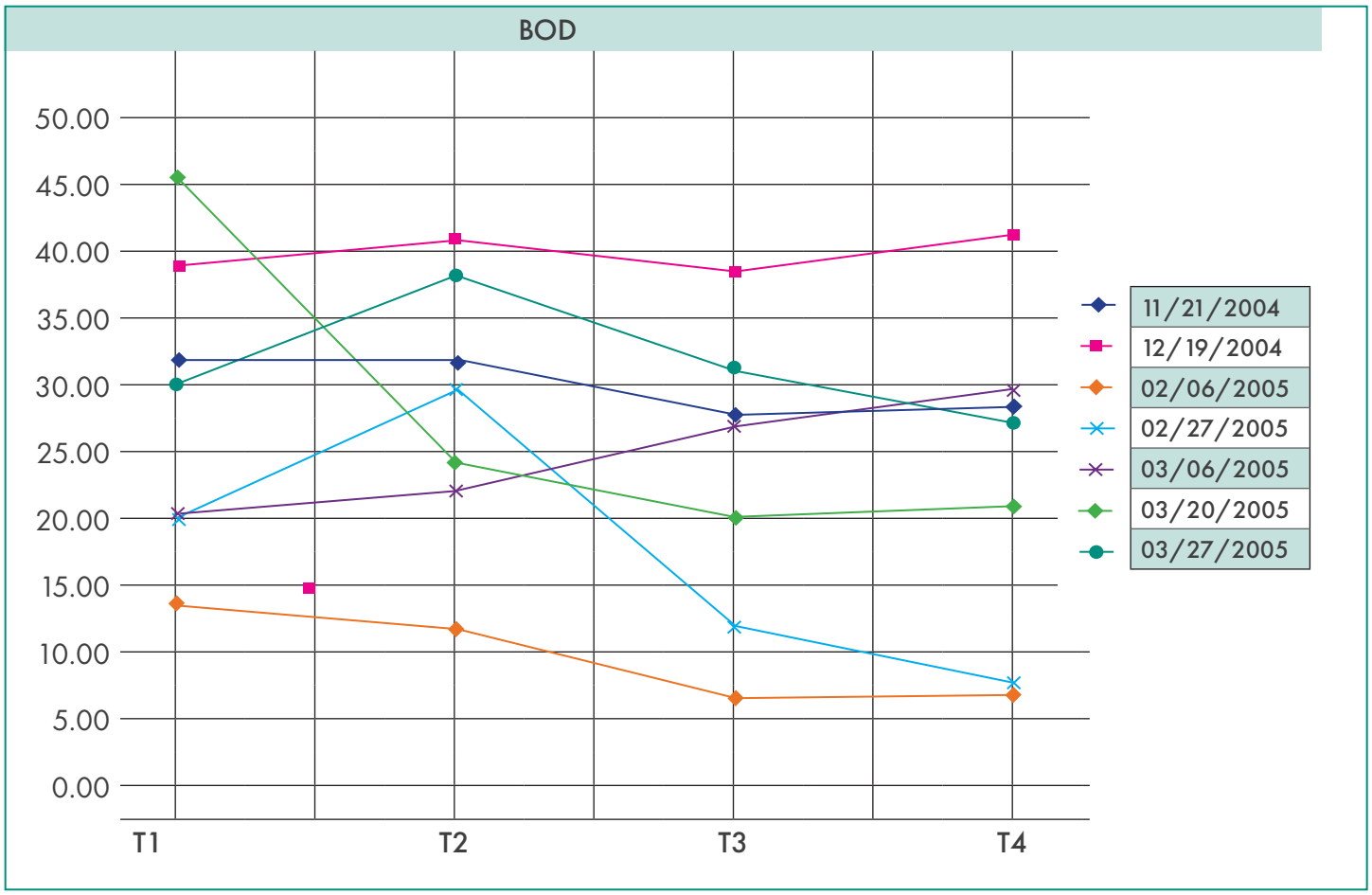
Date	T1	T2	T3	T4	Remarks
11/21/2004	39.80	40.40	41.00	36.20	Inoculation
12/19/2004	67.60	67.70	68.20	60.50	Not much change noted
02/06/2005	30.50	23.20	11.20	12.90	about 60% improvement at T3 and T4
02/27/2005	11.40	28.10	12.20	2.80	Water clarity at T4 is about 1 m
03/06/2005	39.30	35.70	37.10	40.40	Affected by dumping and snow
03/20/2005	58.10	53.40	47.20	38.90	System recovered within two weeks
03/27/2005	45.70	52.10	49.20	42.60	Affected by cement factory waste

Total Nitrogen TN (mg/l)

Date	T1	T2	T3	T4	Remarks
11/21/2004	11.04	15.15	16.12	15.34	Inoculation
12/19/2004	13.48	14.58	12.93	13.48	Not much change noted
02/06/2005	21.50	18.90	13.80	12.40	about 40% improvement at T3 and T4
02/27/2005	8.19	7.37	8.47	7.78	
03/06/2005	13.26	13.26	13.81	12.85	Affected by dumping and snow
03/20/2005	16.41	13.81	10.93	10.10	System recovered within two weeks
03/27/2005	14.77	9.29	9.70	8.50	Affected by cement factory waste

Total Phosphate TP (mg/l)

Date	T1	T2	T3	T4	Remarks
11/21/2004	1.90	1.64	1.73	2.03	Inoculation
12/19/2004	2.23	2.39	2.52	2.61	Not much change noted
02/06/2005	1.55	1.42	0.96	0.84	about 40% improvement at T3 and T4
02/27/2005	1.40	1.61	1.37	1.12	
03/06/2005	1.49	1.66	1.67	1.74	Affected by dumping and snow
03/20/2005	2.60	2.39	2.08	2.04	System recovered within two weeks
03/27/2005	1.68	1.93	1.71	1.75	Affected by cement factory waste


BOD
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T1
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11/21/2004
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02/06/2005
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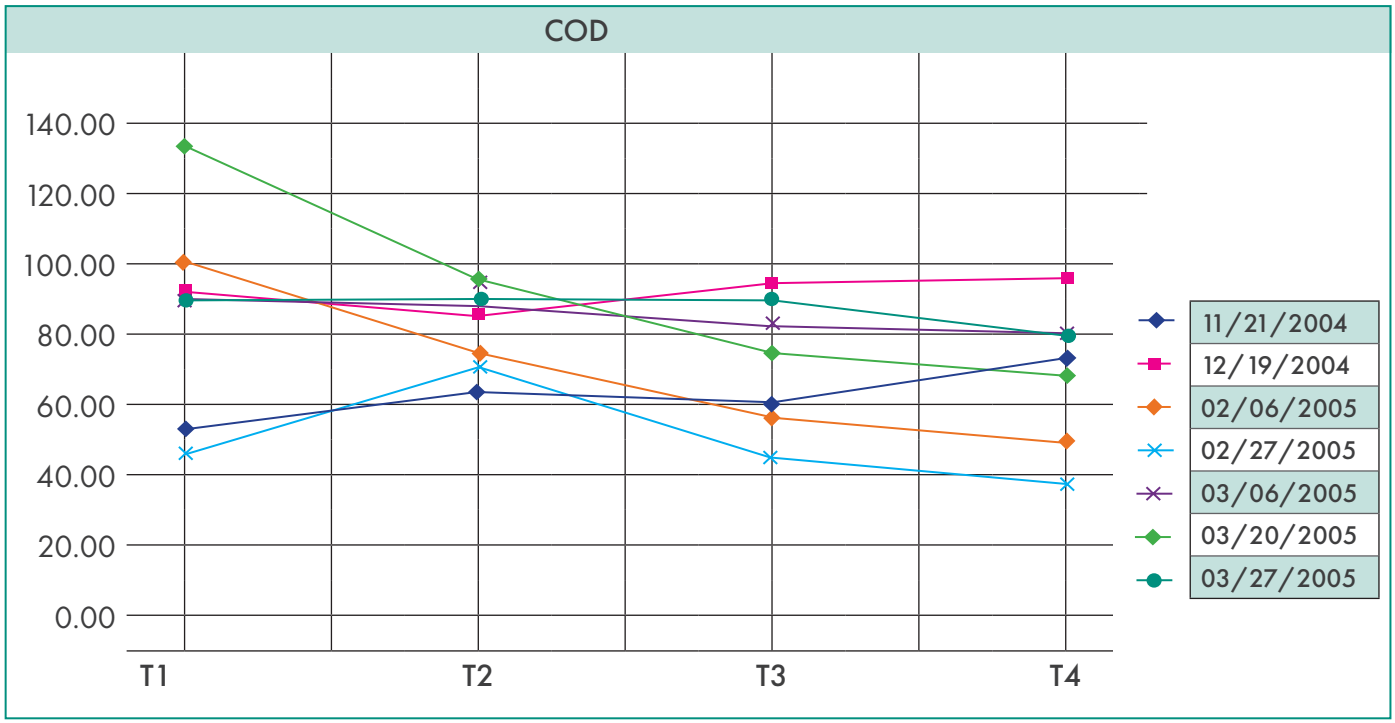
03/27/2005


COD
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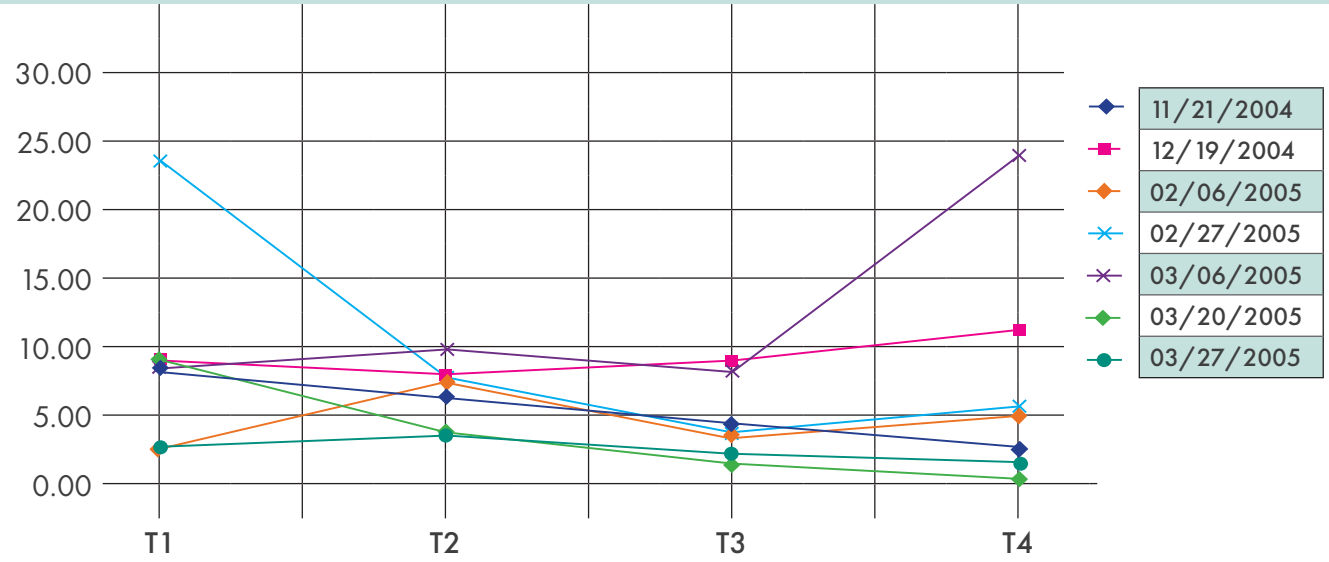
TSS



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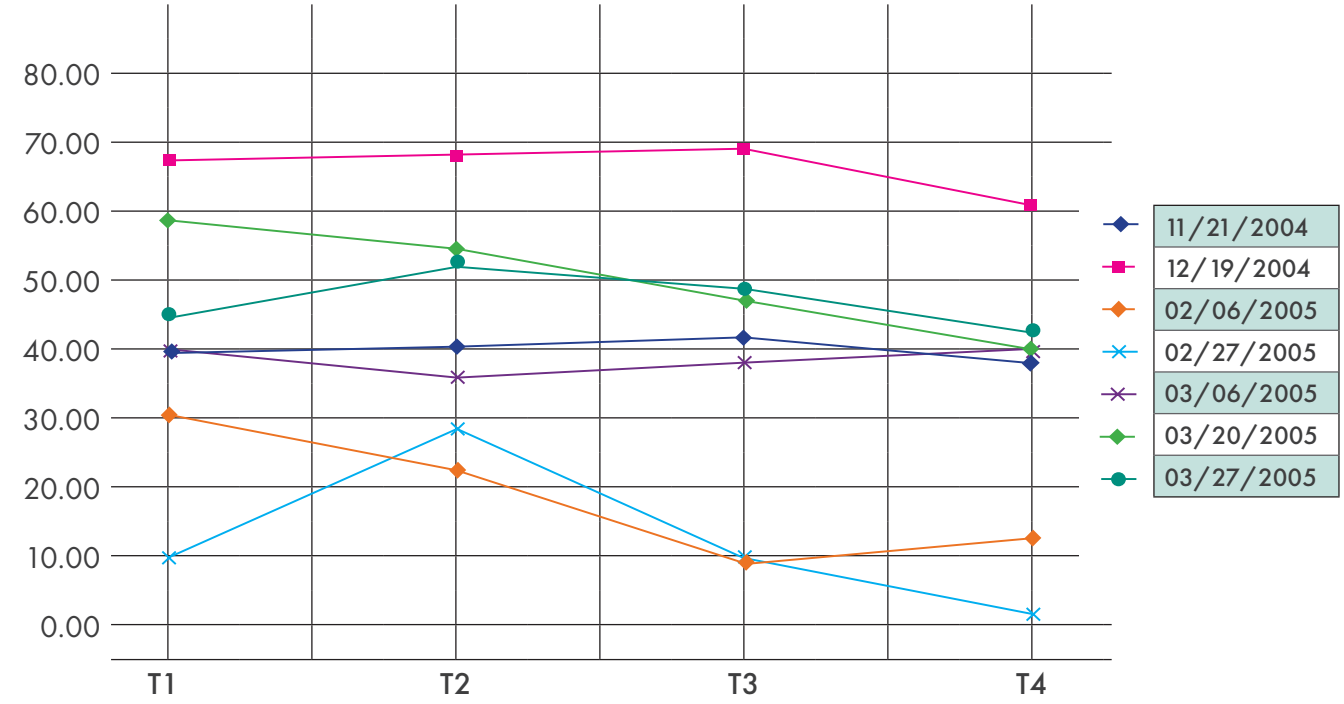

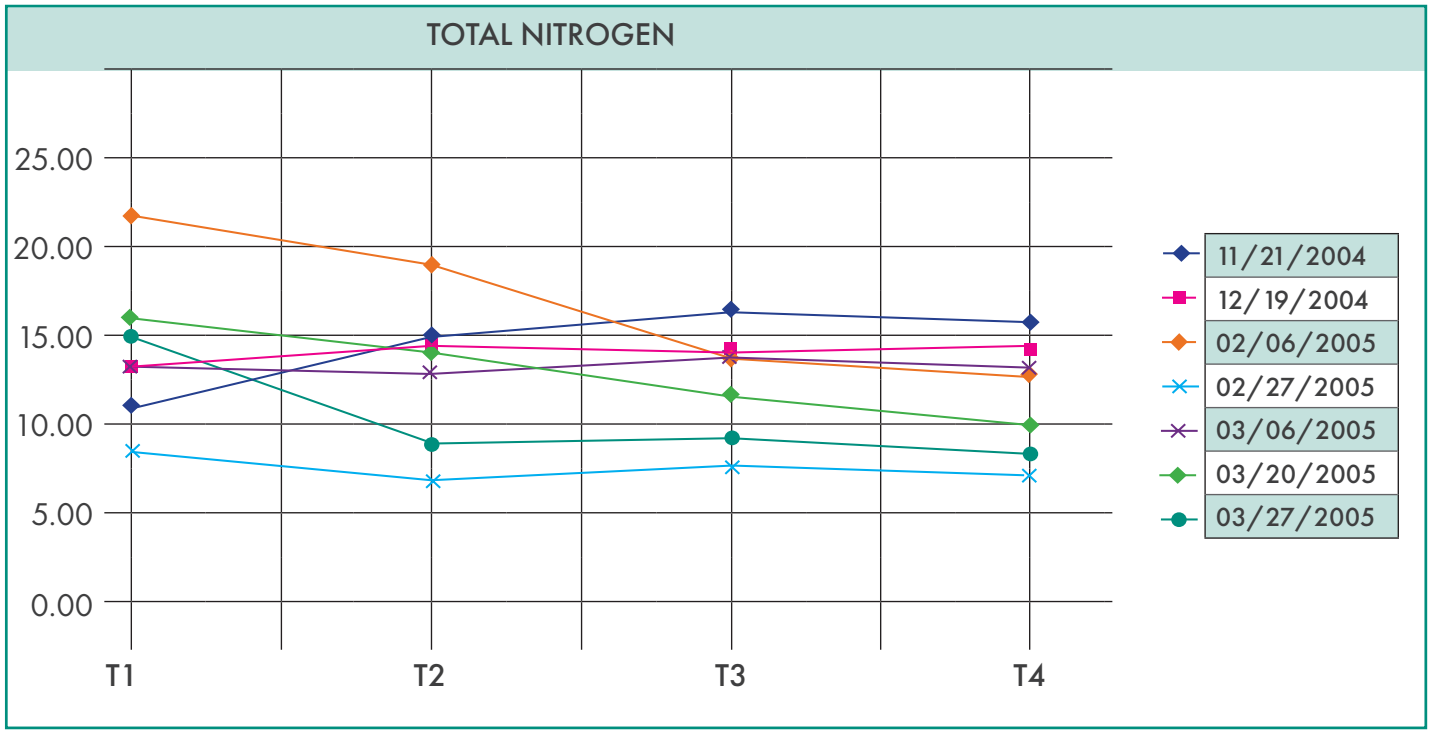

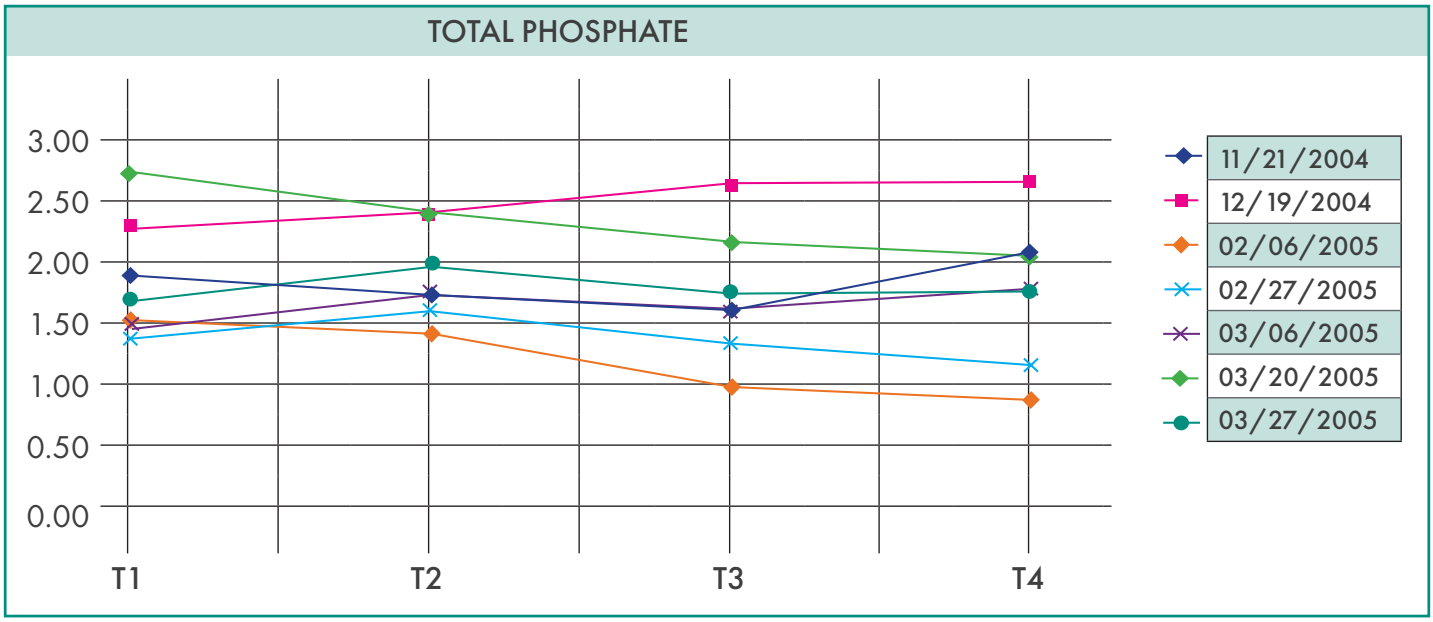

Fig. 10: *TSS of A, B, C, D sample for week by week*

The bad odor along the test zone was drastically reduced within one week of inoculation and was practically eliminated two weeks after inoculation. The river has remained odor free throughout the trial period. However, there was no change in bad odor upstream during the same period, thus confirming that Ecological Laboratories' Microbe-Lift Technology products are very effective in odor reduction. This has also been corroborated by verbal surveys with local residents along the river.

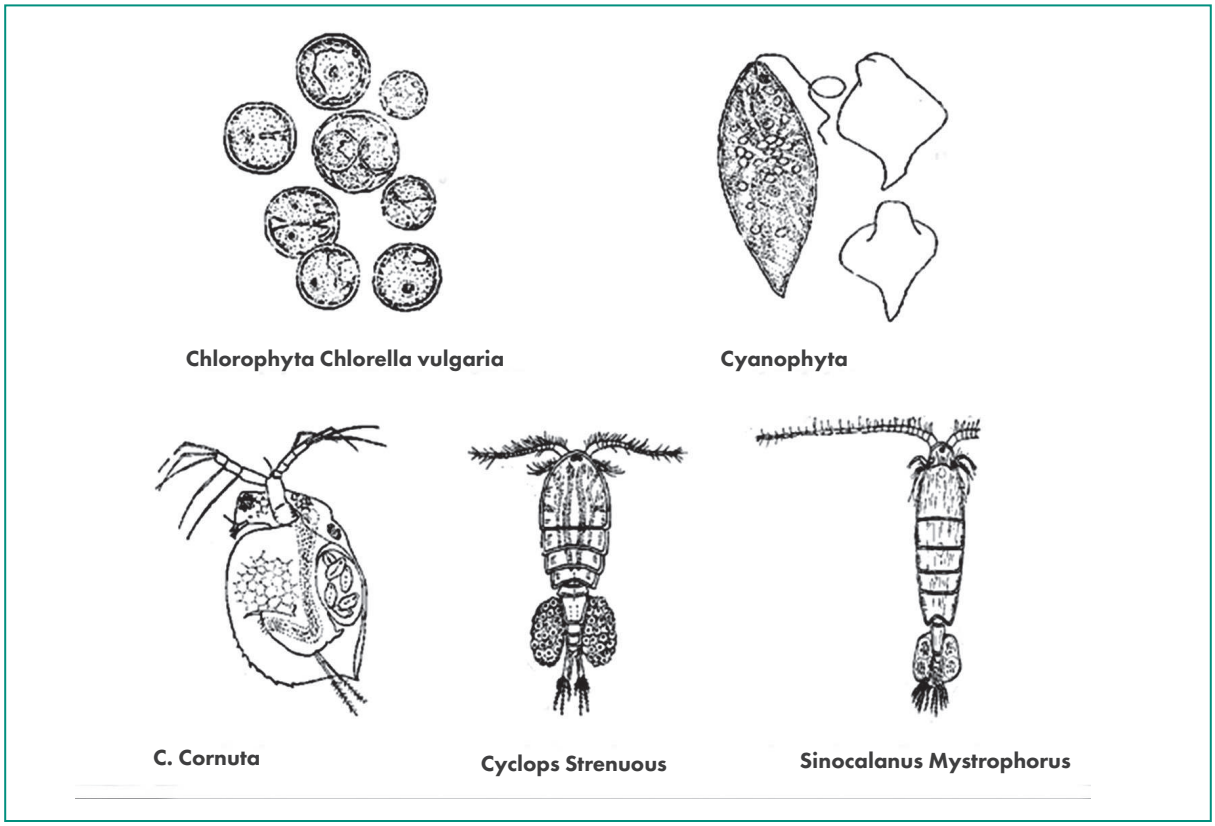

Fig. 4: *Microorganism found in Trial Zone water.*

The various types of microorganisms in the water were monitored during the trial period. 80% of plankton found at the beginning of the trial was Cyanophyta and Chlorophyta. The high percentage of these two types of plankton indicates that the water is heavily polluted. As the water quality improved in Feb 2005 at T3 and T4 locations, large amounts of Chrysophyta and Xanthophyta type of plankton appeared there, in line with water quality improvement. Protozoa type organisms were hardly seen in Xiba River before the trial. Large number of Protozoa and metazoan such as C. Cornuta, Cyclops strenuous and Sinocalanus Mystrophorus appeared at T3 and T4 locations in Jan and Feb 2005. Even kingfishers were attracted to the river by the presence of the small fish.

Fig 4 shows some of the microorganisms described above. Larger protozoa and metazoan such as Rotifera which live on small protozoa and plankton were found in extremely large quantities in late February 2005. Clusters of small fishes also appeared at T4 areas in late February 2005. Even kingfishers were attracted to the river by the presence of the small fish. Fig 4 shows some of the microorganisms described above.

On 26th Feb 2005, a very distinct improvement on the water from T1 to T4 was observed as shown in Fig 5 below.

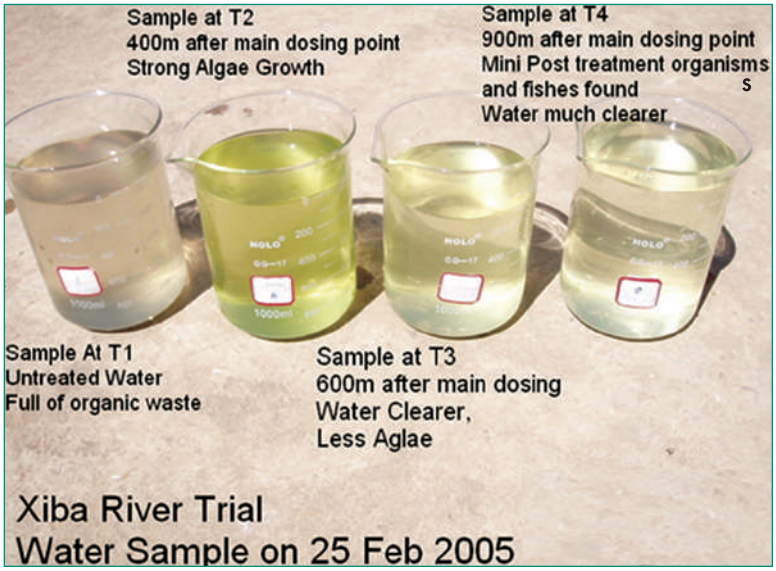

Fig 5: *Comparison of Water Sample from T1 to T4 on 25th Feb 2005*

The water before treatment at T1 was light grey with hardly any sign of life presence. At T2 where the biomedia is located, the water turbidity increased drastically due to the presence of large quantity of bacteria, plankton and algae. The water appeared very greenish. Protozoa and metazoan appeared at T3 further downstream, helping to reduce the algae content, giving the water a cleaner appearance. At T4, which is approximately 7 hours flowing time from D1, huge populations of larger protozoa and metazoan were eaten by the small fishes found there. The water looked very much cleaner with a transparency of more than 0.8m deep with underwater plants clearly visible. The presence of fish further confirms that **Ecologicals'** microbial formulations are non-pathogenic and NOT harmful to higher forms of living organisms. As the protozoa and metazoan moves upstream and more fishes move in the test zone, it is expected that water at T3 and T4 can easily achieve a standard close to level-three where there is significant water clarity and fishes swimming in the river. This ideal condition with fishes swimming gracefully in the river is the ultimate objective every government authority would like to achieve. It is possible, while using formulations manufactured by **Ecological Laboratories** to rehabilitate polluted rivers such as Xiba River with slow flowing water such that it attains the ideal environment with its natural ecological balance.

It is unfortunate in the case of Xiba River, the trial project was unable to sustain the above condition due to the regular blatant discharge of huge volumes of polluted wastewater although, despite this,, the river demonstrated more resiliency and the ability to recover faster from these events.

Fig.6: *D water sampling from Fig. 5*

Fig.7: *The fish appear in the Xiba River*

Conclusion

a) Ability of MICROBE-LIFT® technology products in rehabilitating river.

The trial project has concluded positively that treatment is effective in rehabilitating a flowing river as achieved on 27th Feb 2004. It took three months from inoculation to achieve significant water parameter reduction, a period which was in line with the manufacturer's expectations of 90 to 120 days. This was achieved even with the unexpected low temperatures in Nov and Dec 2004 and interruption of the project by repeated huge dumping of waste water into the river.

b) Effect on odor reduction by MICROBE-LIFT® technology

The trial project has also concluded very positively that treatment is very effective in odor reduction and is non-pathogenic and not harmful to fishes, as claimed by the manufacturer.

c) Effect of pH Changes

The water at Xiba River has a pH ranging from 7.0 to 7.8 which is ideal for the survival and multiplication of microbes. This is an ideal pH range for this technology.

d) Effect of Temperature Changes

The trial results do show that the product's effectiveness reduces in temperatures below 10°C.

e) Conclusion on parameter measurement

The positive results achieved in Feb 2005 leads to the conclusion that Ecological Laboratories product formulations are effective in bringing down BOD, COD, TSS, Turbidity, Total Nitrogen and Total Phosphorous by half from T1 to T4, which represents only an average of 7 hours retention time. Although the water parameter at T4 has not achieved a level-three standard as set out by the authorities, the product manufacturer is confident that a level-three standard or a standard at least close to level-three can be achieved in a complete river treatment where the bacteria has a much longer time to react and treat the water. Practical steps must be taken to prevent blatant dumping of huge volumes of untreated wastewater into the river, particularly chemical waste that inhibits the bacteria growth such as the highly alkaline cement plant waste.

f) Dosage

The experiment commenced with an inoculation at 4.7 ppm, which is, less than half the 10 ppm recommended by the manufacturer. However, it was subsequently adjusted to approximately 1 ppm per day based on the daily flow rate. This dosing is higher than the recommendation for a stagnant lagoon of 1 to 2 ppm per week. The higher dosing was recommended to compensate for the irregular flow pattern of the river and the short retention time of the test zone. In a complete river project where the length of treatment is long, a much lower dosing is recommended.

g) Effect of Biomedia

Although biomedia was introduced for a 510m long stretch at the beginning part of the trial zone, the actual effects of biomedia could not be measured because there are no control cases for comparison. We strongly believe that the biomedia helps in retaining part of the microbes as the water flows. This is likely one of the contributing factors for success in the trial.

h) Recommendations are proposed for future river treatment with MICROBE-LIFT® technology:-

1. It is strongly recommended that dosing of MICROBE-LIFT® technology for flowing rivers be done through a continuous automatic dripping dispenser rather than direct pouring into the river as has been done in this trial project. This is to prevent large quantity of bacteria being washed off if flow is inconsistent.
2. A holding pond of suitable size can be constructed to divert some wastewater into the pond to culture MICROBE-LIFT® bacteria, to increase the bacteria count before its release into the river. The continuous dripping can be done at the inlet of this breeding pond. In this way, the usage of MICROBE-LIFT® can be reduced by several fold thereby make any river treatment very economical. The principal supplier of MICROBE-LIFT® can provide a detailed project feasibility evaluation to the client.
3. Introduction of biomedia along the river with appropriate design and quantity is recommended for rivers with water flow rate exceeding 2 meters per minute. MICROBE-LIFT® principal supplier can advise the client on an economical biomedia design and sizing.

This report jointly prepared by Prof Hu Kailin of Kunming University of Science and Technology and Mr Goh Kwang Beng of **Ecological Laboratories.**

For more information on MICROBE-LIFT® Technology contact
Ecological Laboratories Inc.
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CS17201