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Bioremediation of Lakes: Myths and Realities

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ABSTRACT

Bioremediation is a treatment process that uses naturally occurring microorganisms (yeast, fungi or bacteria) to breakdown or degrade hazardous substances into less toxic or non-toxic substances. Several lakes have undergone bioremediation in recent years. Some myths have surfaced due to improper execution of the technology. The assumptions have been that mechanical aeration systems are critical to bioremediation, and that this is a slow process and is not appropriate in tropical conditions. A study of the bioremediation projects over three different regions in the world i.e. Central Europe, Middle East and India shows that if executed properly then bioremediation would be a practical tool for Lake Management. It is very useful for controlling the water parameters and also various pathogenic microorganisms. Bioremediation can be swift and also implemented with little or no mechanical aeration systems. Bioremediation may not be applicable in each and every case. It requires highly specialized knowledge, and can be applied in most cases of lake remediation, including all kinds of weather conditions.

Keywords: Bioaugmentation, Aeration, Bacteria, Eutrophication, Destratification, Urban lakes, Water hyacinth

INTRODUCTION

Bioremediation is a treatment process that uses naturally occurring microorganisms (yeast, fungi or bacteria) to breakdown or degrade hazardous substances into less toxic or non-toxic substances.

Typically, the components of a Lake Bioremediation project execution involve physical cleaning, aeration and bioaugmentation.

Physical Cleaning is the removal of undesirable pollutants that can be removed physically either through manual or mechanical means. Physical cleaning includes removal of weeds as well as floating solid waste. Aeration of the lake is needed for mixing the different thermal layers of the lake system and hence destratify the lake. The purpose is to disturb the hypolimnion so that these lower most layers can be exposed to atmospheric air. This increases the dissolved oxygen in the water and provides oxygen for the microorganisms to degrade the pollutants. Appropriate microbial cultures or a consortium of microbes are added to the lake to degrade the pollutants and restore the eco-balance. The objective is to reduce Biological Oxygen Demand (BOD), Nitrogen in the form of nitrates, nitrites and ammonia, and phosphorus. The key to any bioremediation process is the application of specific microorganisms to achieve specific transformations. The bacteria that derive their energy from chemical energy are called chemotrophs, and bacteria that use organic compounds as the principle carbon source are called heterotrophs. Bacteria that have both traits are called chemoheterotrophs, and are the most important organisms for bioremediation. A higher degree of sophistication in the application of specific microorganisms targets inhibition of pathogenic organisms.

Several lakes have undergone bioremediation both in India and abroad in recent times. Some of these lakes have had stupendous success whereas others have seen re-emergence of weeds and deterioration of the water body. These mixed results have perpetuated some myths about the technology.

Some of these myths are

1. Bioremediation is a slow process and takes a long time to show results.
2. Expensive aeration systems are critical for the success of bioremediation.
3. Bioremediation is always the best solution.
4. Bioremediation does not work in tropical conditions.

Background of the Lakes Bioremediated

Lake Bioremediation was applied in several smaller lakes (less than 100 Hectares) in Central Europe, Middle East and India. The lakes that were bioremediated are as follows

Central Europe:

Most of the lakes bioremediated in Central Europe were all fishing lakes with a depth of less than 5 metres. The water quality was very poor, high algae number, high nutrient concentrations, high pathogenic count, and fish kills were quite common

in summer. Out of the 13 lakes bioremediated, the lakes considered for discussion are
Nagybivalyos Lake
Felso Lake
Sajoszogedi Lake
Banki Lake

Nagybivalyos always struggles with high pollutant load as it receives the water from the tertiary treated pond of a sewage treatment plant. This Sewage Plant is not very efficient and releases poorly treated wastewater. There is a constant inflow of nutrient rich water to the lake. This lake was treated for 3 months from June 2007 to Sept 2007.

Felso lake is located at a lower gradient very near to Nagybivalyos Lake, and hence receives the same water but in a better condition. This lake was treated for 3 months from June 2007 to Sept 2007.

Sajoszogedi Lake had high nutrient and organic load. It was a former gravel mine pit. The water quality was very poor, with high algal count, high nutrient concentration, and high pathogenic count. Regular fish kills was also observed. Tests had shown that the fish kills were due to Aeromonas Hydrophila and Spherosporosis. This lake was treated for 2 months in July and August 2007. The objective here was to make the lake viable for swimming for the Triathlon World Cup held in August, 2007.

Banki Lake is fed only by underground streams, but because of Bank village on its periphery and agricultural lands, it gets massive nutrient loads. Nutrient loads increase during rains due to agricultural run-offs. This lake is a tourist attraction and has a lot of recreational activities such as fishing and swimming. Another big concern here was the coliform and enterococcus count.

Middle East: The lakes in the middle east were very small and had high algal concentration. During the peak summer the lake water in Zabeel Park reached a TDS level of 80,000. This was due to contamination of the ground water with the sea water. These lakes serve only for aesthetics and do not have any activity in them. The lakes discussed are
Zabeel Park
Naqeel Lake

India:

The lakes in India were hypertrophic. These were small, but dead lakes. There were growths of several macrophytes, and very highly polluted due to urban settlements around the lake. Both these lakes had a lot of religious activities which provided constant source of pollutants. The lakes discussed herein are
Masunda Lake
Railadevi Lake

Masunda lake is situated in the heart of the city. It was a highly polluted lake and needed urgent attention. The local authorities leased the lake to a private contractor to carry out fishing and boating activities.

Railadevi lake is also situated in highly urbanized area of Thane city. It had extremely large number of macrophytes of various types. The lake had been dredged partially by the local authorities that exposed the different layers of sludge to the water. Consequently the water had a green pea soup appearance.

Execution

Physical Cleaning: There was no need of any physical cleaning in the lakes in Central Europe and in the Middle East. Physical cleaning was required for the lakes in India at the onset of execution of the bioremediation process and also on an on-going process. This was necessary due to urban settlements around the lake and immersion of idols during festivals and dumping of offerings from religious rituals.

There were several different types of macrophytes that were removed manually. Flowers or remnants of religious and community practices had to be removed so that they do not serve as reservoirs of further pollution.

Aeration of the Lake: The need for aeration systems was arrived at by evaluating factors such as water parameters of the lake, ambient temperatures, history of pollution, wind conditions, and depth of the lake.

An aeration system was installed in Railadevi Lake. The aeration system consisted of two Rotary Vane Compressors of 0.75 HP with 24 diffusers throughout the lake. This aeration was functioning for 24 hours for the first three months and thereafter reduced to 12 hours per day.

Zabeel Park Lake in UAE had existing fountains installed as part of its aesthetics. This fountain that was operated only in the evening was operated for 12 hours a day.

In Central Europe, only Bank Lake had two venturi type 0.5 HP aerators. None of the other lakes had any aeration systems in place and could not invest in any aeration system.

Some makeshift circulation and mixing was achieved by utilizing existing pumps or activities such as boating or jet skiing.

Bioagumentation

In all cases, microbial consortiums which contained one or more of the following organisms in varied proportions were applied to the lakes. These solid compositions contained Bacillus sp., Azotobacter sp. Flavobacterium sp., Streptomyces sp., Aspergillus sp., Trichoderma sp., Pseudomonas sp. and Saccaromyces cerevisiae.

The concentration and frequency of dosing of the microbial cultures was done based on various

factors such as the water parameters, algal concentration, volume of the lake and ambient temperatures.

The only exception was in the case of Zabeel Park when the TDS went beyond 50,000 the addition of microbial cultures stopped and enzymes were added.

Community Education:

The lake had to be maintained after the reversal of pollution, and community education becomes critical. If the lake continues to get polluted it will lose its eco-balance and go back to its original polluted state. All the stakeholders in the case of each lake such as the caretaker, local governing body and community leaders were educated on the importance of keeping the lake clean.

RESULTS

The Nagybivalyos lake did not have any algal blooms throughout the summer, and over the course of the treatment there was a 75% reduction in the algae number. A significant decrease in ammonia and nitrates was also observed. Phosphate reduction was there but was not very remarkable. This may be due to the constant supply of the phosphate coming from the tertiary treated wastewater from the plant. The water parameters are tabulated in Table 1.

Table 1: Periodic water parameters of Nagybivalyos Lake

Parameters	14th June 2007	24th Sep 2007
NH4+ (mg/l)	0.73	0.37
NH3 (free) (mg/l)	0.2	0.04
NO2- (mg/l)	0.91	0.24
NO3- (mg/l)	40.31	39
$PO4^3$- (mg/l)	0.61	0.92
Green Algae (%)	37	9
Bluegreen Algae (%)	9	8
Diatomes (%)	38	41
Ciliates (%)	16	42

The Felso lake showed remarkable improvement within one month of treatment. This was because this lake was getting the treated water from the Nagybivalyos lake. The dissolved oxygen levels improved within one week of start of treatment. The water parameters are tabulated in Table 2

Sajoszogedi Lake had excellent water parameters in time for the sport event. The water showed lower numbers of Coliform, Enterococcus and Clostridium. The fish kills were stopped within one week of treatment of the lake. The water parameters are tabulated in Table 3.

Table 2: Periodic water parameters of Felso Lake

Parameters	14th June 2007	24th Sep 2007
NH4+ (mg/l)	0.82	0.12
NH3 (free) (mg/l)	0.09	0.005
NO2- (mg/l)	0.24	0.17
NO3- (mg/l)	37.21	18
$PO4^3$- (mg/l)	0.31	0.09
Green Algae (%)	21	6
Bluegreen Algae (%)	2	7
Diatomes (%)	52	20
Ciliates (%)	25	67

Table 3: Periodic water parameters of Sajószögedi Lake

Parameters	6th July 2007	24th Sep 2007
NH4+ (mg/l)	0.39	0.13
NH3 (free) (mg/l)	0.02	0.00
NO2- (mg/l)	0.21	0.04
NO3- (mg/l)	19.5	5.8
$PO4^3$- (mg/l)	0.43	0.2
Green Algae (%)	10	18
Bluegreen Algae (%)	8	8
Diatomes (%)	34	51
Ciliates (%)	48	23

Banki lake showed significant decrease in ammonia, nitrite and nitrates. The phosphate was down by 50% in 2 months. There was significant decrease in E. coli and Enterococcus count. Dissolved oxygen levels stabilized within one week. The water parameters are tabulated in Table 4

Table 4: Periodic water parameters of Bánki Lake

Parameters	10th Aug 2007	25th Sep 2007
NH4+ (mg/l)	0.14	0.18
NH3 (free) (mg/l)	0	0
NO2- (mg/l)	0.09	0.01
NO3- (mg/l)	10.5	21
$PO4^3$- (mg/l)	0.11	0.09
Green Algae (%)	17	8
Bluegreen Algae (%)	3	2
Diatoms (%)	38	41
Ciliates (%)	42	49

Zabeel Park showed significant drop of algal concentration as evidenced by clarifying of the green water. There was a interim reversal due to increase in Total Dissolved Solids to 80,000. The

bioaugmentation with microorganisms was stopped and enzyme treatment was commenced.

Naqeel lake showed drop of algal concentration and clarification of water.

Masunda lake has been maintained as per the norms. The lake is currently being used for recreation, boating and commercial fishing activities. The contractor has claimed improvement in his fishing economics.

Railadevi lake showed complete elimination of hyacinths. This is very evident from the photographs in Figure 1 and Figure 2. The lake showed significant rise in dissolved oxygen. The water parameters showed significant improvement. The results of Railadevi Lake are tabulated in Table 5 and Table 6.

Figure 1. Photograph of Railadevi Lake showing macrophytes before bioremediation.

Figure 2. Photograph of Railadevi Lake after bioremediation

Table 5: Periodic water parameters of Railadevi Lake – Top water layer

Parameters	April'03	Aug'05
DO (mg/l)	1.5	7.8
BOD (mg/l)	22	11
COD (mg/l)	120	20
PO4 (mg/l)	7.1	0.031
NO3 (mg/l)	3.8	0.028

Table 6: Periodic water parameters of Railadevi Lake – Bottom water layer

Parameters	April'03	Aug'05
DO (mg/l)	0.3	7.6
BOD (mg/l)	24	14
COD (mg/l)	132	25
PO4 (mg/l)	11.04	0.043
NO3 (mg/l)	6.8	0.031

DISCUSSION

The reversal of pollution as indicated by water quality parameters, algal parameters and dissolved oxygen levels, was very rapid in the Central European lakes. The water parameters improved under one month and the dissolved oxygen levels improved within a week of bioaugmentation. The fact that these improvements came about in these lakes without any aeration system was very remarkable. The entire process was done during the peak summer months when the ambient temperatures were above 32^{o}C. A graphical representation of the average water parameter levels across the board in these various Central European Lakes is seen in Figure 3.

The pollution reversal was also remarkable in the case of the lakes in the Middle East wherein the ambient temperature exceeded 45^{o}C. It took an average of 3 months for major reversal. Whereas it took over 12 months to see remarkable results in the case of Railadevi Lake. The bigger challenge to surmount in the case of Indian lakes were cultural issues and the religious practices of immersing deity idols in the lake, and also the practice of religious offerings to the water bodies. The graphical representation of this data is seen in Figure 4 and Figure 5.

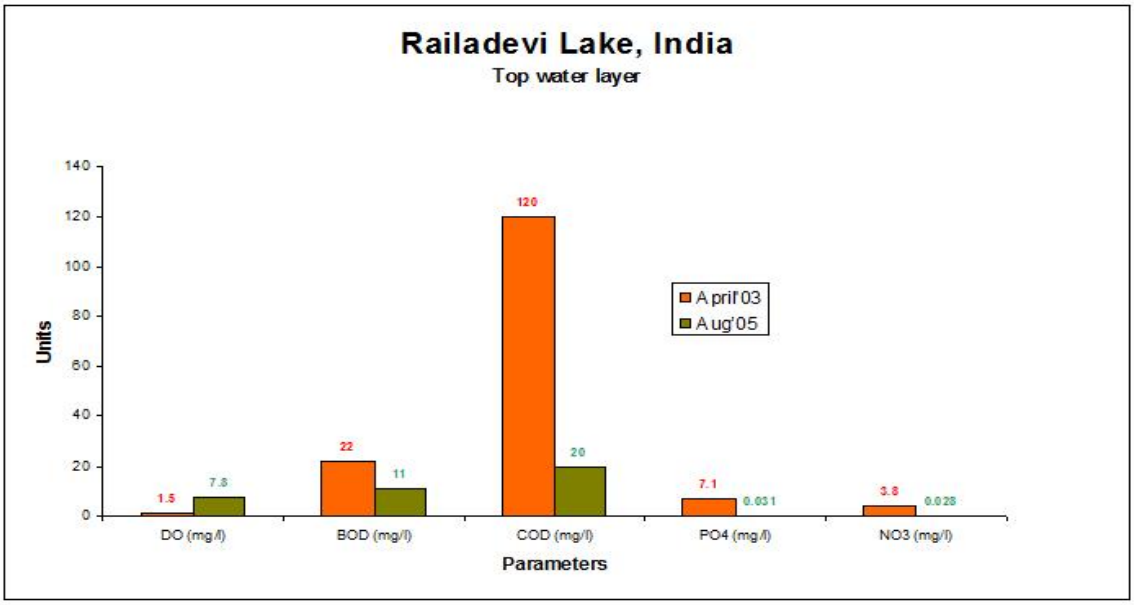

Figure 3: Average results of all four lakes in Central Europe before and after bioremediation

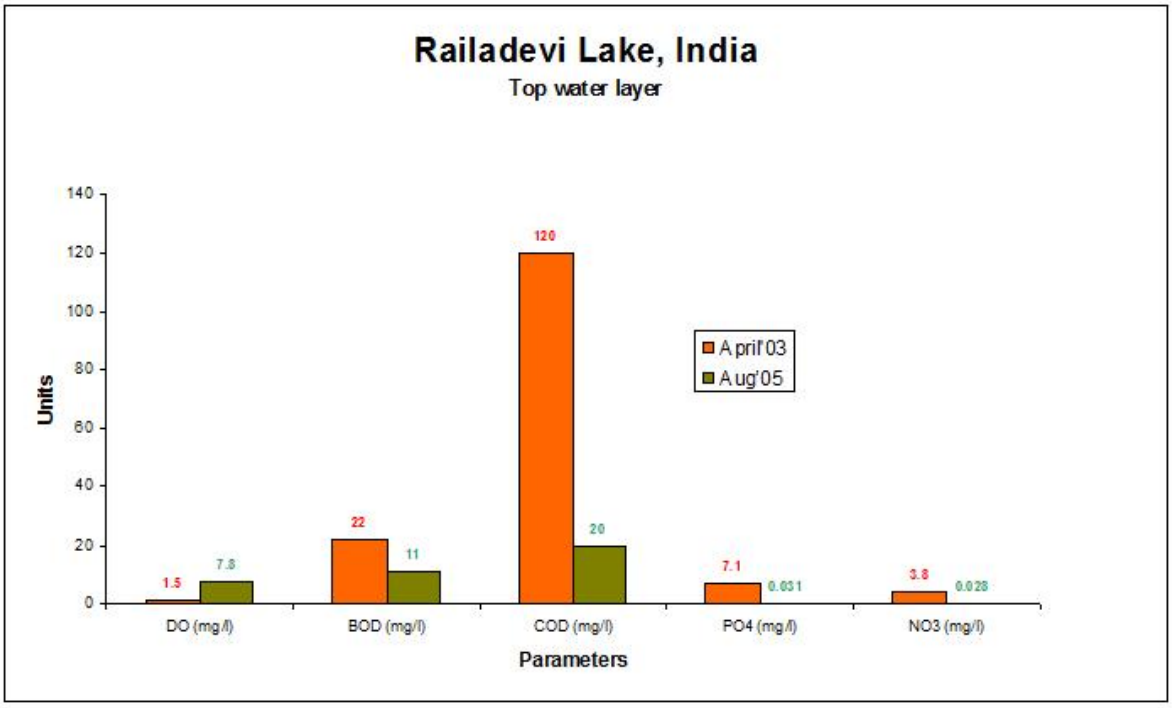

Figure 4: Water parameters of top water layer of Railadevi Lake before and after bioremediation

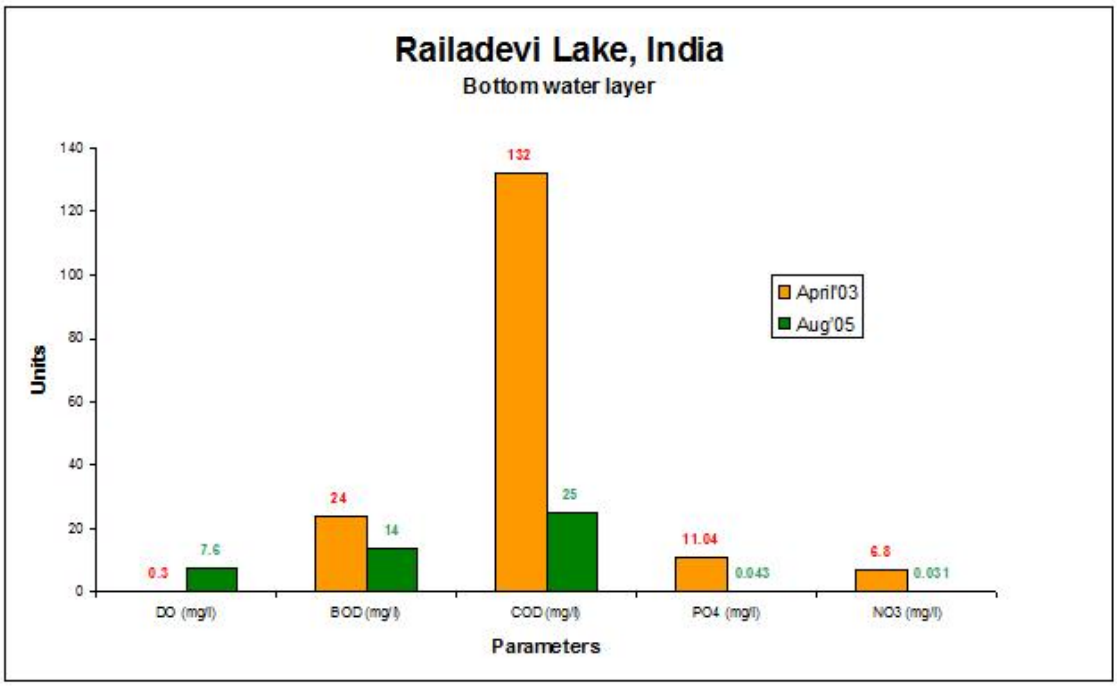

Figure 5: Water parameters of bottom water layer of Railadevi Lake before and after bioremediation

The noteworthy observation was the swift improvement of water quality without any significant investment in aeration systems in the European lakes. This is possible due to the lakes being shallow. Even in the lakes in the Middle East bioremediation was possible with the existing fountains, and did not require any additional investments on equipment.

Bioremediation may not be employed in each and every case of lake pollution. This was evident in the case of Zabeel Park lake where the TDS started climbing to 80,000 ppm. At this high TDS it is difficult for the microorganisms to survive and carry out their functionality. Therefore, a living system has to be substituted by a non-living system, such as an enzyme system.

It was further established that bioremediation is effective in the Middle East and India where the ambient temperatures exceed 40^{o}C during the summer. Though it is not easy to surmount the aggressive growth of algae in the high heat, this can be overcome by effective dosing strategies.

Bioremediation is an effective strategy for most of the small to mid size lakes. A closer look shows a correlation of better outcome with better control of contributing factors for lake pollution, in conjunction with bioremediation.

CONCLUSION

Bioremediation can be applied as part of an effective lake management programme. It can be manipulated to act expeditiously and sometimes without any aeration systems in place. Aeration systems are supportive measures and may not be critical in lake remediation. Bioremediation may not be appropriate for each and every case of lake pollution, and may require support from other technologies. However, it is effective in hot tropical climates.

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