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Bio-Augmentation Technology in Textile Mill Wastewater Management: A Case Study

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Abstract: Technological advancements followed by industrialization on one hand and exploding population on the other are polluting the water significantly. Thus demand for quality as well as clean water supply in last few decades has been increased tremendously for the benefit of mankind. Industries like steel/coke plants, textiles, tanneries, refineries, pulp and paper industries, distilleries, metal processing and electroplating units are the major polluters of water and its environment. Most of these mills are generating a large quantity of wastewater with high organic load, high odor due to presence of sulfides, aromatic and aliphatic hydrocarbons, fats, oils and greases; including heavy metal complexes even cyanide (coke plant waste). Conventional activated sludge process may not be sufficient enough to tackle all these problems and meet the discharge limits set by the pollution control boards. Waste water generated from these industries contaminated with aforesaid contaminants can be managed very effectively by a recently developed technology in the field of environment known as Bio-augmentation Technology-an unique technology of augmenting or supplementing the existing bacterial population with specifically adapted bacteria that can reduce waste water faster or capable of degrading compounds that are primarily non-biodegradable. It enables plants to meet discharge limits with existing facilities in a cost effective manner without going for any capital investment. In this study, a successful application of Bio-augmentation technology using Augment P5 in a textile plant effluent has been presented as a case study. More than 50% improvement in plant efficiency with respect to biological degradation (BOD) of wastewater could be achieved. In case of TSS and COD reduction, the values in terms of improvement in plant/system efficiency were observed to be around 47 and 53%, respectively.

Key words: Bio-augmentation technology, textile mill, wastewater, augment P5, plant/system efficiency

INTRODUCTION

An awareness of environmental problems and potential hazards caused by industrial wastewater has prompted many countries to limit the discharge of polluting effluents into receiving waters (Ezeronye and Okerentugba, 1999; Okerentugba and Ezeronye, 2003; Ezeronye and Ugbogu, 2004; Ezeronye and Ugbogu, 2005).

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The large volumes of water required for the preparation and dyeing of cloth have hampered the textile industry, from its beginnings. More recently, water consumption and waste generation have become considerable concerns for textile manufacturers and finishers.

Textile industry wastewater is characterized by measurements of Biochemical Onygen Demand (BOD), Chemical Onygen Demand (COD and TSS color, heavy metals and TDS. The real hazards caused by the color and solids in textile waste are dye toxicity and the ability of the coloring agents to interfere with the transmission of light through the water, thus hindering photosynthesis in aquatic plants. The dyes present in textile effluent impart persistent color to the receiving streams and interfere with photosynthesis of the phytoplankton (Cunningham and Siago, 2001). Other physical characteristics of the wastewater include odor, change in dissolved oxygen, presence of insoluble substances and corrosive properties. The colloidal and suspended purities cause turbidity in the receiving streams. The dissolved minerals may increase salinity of the water and thus may render it unfit for irrigation or consumption. Toxic chemicals such as chromium and sulphites may destroy fishes and microorganisms responsible for self-purification of water in streams. Immediate oxygen demand due to the impurities such as starch, sulphites, nitrites, deplete the dissolve oxygen content of water. Starch cotton debris constitute organic wastes which are oxygen demanding. They can undergo decomposition/degradation by bacterial activity. The chemicals use in the processes may change pH of the effluent and once disposed into the water body affects aquatic lives. Dissolved solids can also form incrustations on the surfaces of sewers and chemicals may cause corrosion of the metallic parts of the sewage treatment plants.

Thus, an effluent that emanates from the production process of textiles, if not properly disposed, can cause serious environmental pollution, sometimes to levels that can threaten human health, livestock, wildlife, aquatic lives and indeed the entire ecosystem. Every production process goes with wastes generation. Various treatment options are available for treatment of textile wastes before disposal. Traditional disposal method such as ocean dumping is now out of place following numerous incidents of severe negative impacts on the environment after years of disposal. Typical examples are the Love Canal episode of the Niagara Falls in the United States of America and the Mina Mata Bay experience in Japan where several tons of mercury was discharged through effluent into the bay and the inhabitants suffered the effect after over thirty years. There are physical and chemical methods, which, in spite of costs, do not always ensure that the contaminants are completely removed (Hardman *et al*., 1993). In recent times there has been a tremendous upsurge in the search for cost-effective and environmentally friendly alternatives to traditional methods for dealing with wastes.

Of all the technologies investigated in waste cleaning, bioremediation has emerged the most desirable approach for cleaning up many environmental pollutants. Bioremediation is a pollution control technology that uses biological systems to catalyze the degradation of or transformation of various toxic chemicals to less harmful forms. The general approaches to bioremediation are to enhance natural biodegradation by native organisms (intrinsic bioremediation), to carry out environmental modification by applying nutrients or aeration (biostimulation), or through addition of microorganisms (bioaugmentation) (Ashoka *et al*., 2002). Bioremediation is similar to the use of plants to restore contaminated sites (Phytoremediation). The ability of microorganisms to transform a variety of chemicals has led to their use in bioremediation processes. A number of microorganisms have since been studied to unfold their degradative abilities in remediation of pollutants.

Biological digestion is the most commonly used process to remove organic matter from wastewater, which are biodegradable. In this process, wastewater treatment plants utilize bacteria cultivated under controlled conditions using organic matter as their food that would otherwise be harmful to the environment and also product of respiration, such as CO_2 in aerobic and CH_4 in anaerobic systems. The bacteria or bugs do not eat in the normal sense of word, instead they secrete enzymes, which in turn break down organic molecules, which pass through the cell and are digested by bacteria. Eventually these digested compounds are converted into new cell matter. The cell matter

Table 1: Effluent standards for discharge into inland surface water

Parameters	Limit
pH	5.5-9.0
TSS (mg L^{-1}, max.)	100
COD (mg L^{-1}, max.)	250
BOD (mg L^{-1}, max.)	30
Oil and Grease (mg L^{-1}, max.)	10

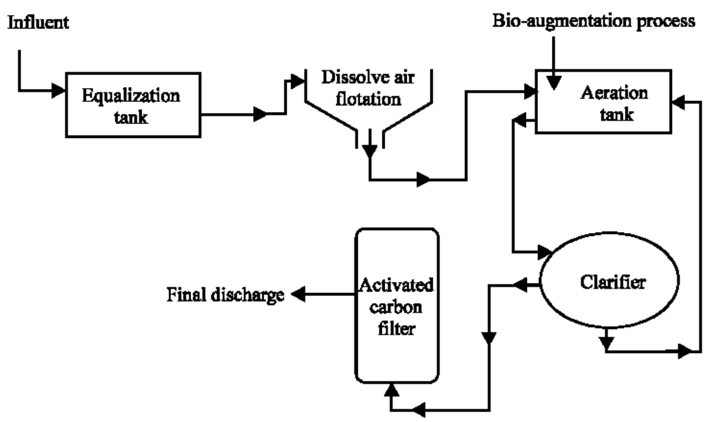

Fig. 1: The plant schematic for effluent treatment operation

is then separated from water flow as sludge and resulting purified water is discharged into a receiving body of water (stream, river or lake). So, in essence what we have in a waste stream, rich in organic contaminants flowing into a waste treatment plant or bug factory. The contaminants are converted to the more bugs, which are then separated from the stream.

The purified stream is then chlorinated and discharged. Since the process deals with living organisms every factor influencing the growth and health of culture must be considered including adequate food supply Food/Micro organsim (F/M) ratio, Mixed Liquor Suspended Solids (MLSS), the nutrients availability, a temperature climate and a relatively uniform environment, free of pH and temperature shocks and similar disturbances. If the system is aerobic, oxygen must be available for respiration. But quite often, the bugs in waste treatment plant are unable to effectively degrade all of the organic contaminants coming into the plant. Further, proper monitoring of above mentioned parameters are often troublesome and these hard working bugs then are unable to degrade properly the organic contaminants and also due to fluctuation in production pattern or system shocks may create conditions that extend beyond their capabilities. Therefore, these conditions often lead to totally uncontrolled situation of a biological waste management system. And sometimes unable to meet the discharge limits set by Pollution Control Board (CPCB, 1995). The effluent standards for discharge into inland surface water for parameter like pH, TSS, COD, BOD and Oil and grease are shown in Table 1.

This situation can be tackled very effectively by Bio-augmentation Technology. So an attempt has been made here on effective implementation of Bio-augmentation Technology, using Augment P5 for degradation of textile mill wastewater. The plant was facing problem during biological degradation of waste by following conventional activated sludge process (Fig. 1).

MATERIALS AND METHODS

The studies were carried out using the wastewater sample collected from ETP of Textile Mill at Ganganagar near Kolkata, India during September 2006-February 2007. The influent and effluent

Table 2: Influent and effluent characteristics before Bio-augmentation

Parameters	Influent characteristics	Effluent characteristics
pH	10.0-11.5	7.4-7.8
TSS (mg L^{-1})	137.0-180	95.0-126
COD (mg L^{-1})	600.0-1000	195.0-265
BOD (mg L^{-1})	230.0-400	26.0-48
Oil and Grease (mg L^{-1})	12.0-18	5.4-7.8

Table 3: Features of Augment P5

Parameters	Typical characteristics
Appearance	Free flowing tan colored powder
Bacterial count	5 billions g^{-1}
pH	Neutral
Odor	Yeast like
Screen mesh size	95% through 10 mesh
Moisture content	15%
Bulk density	0.50-0.61 g cm^{-3}
Standard packing	11 kg

characteristics before and after Bio-augmentation process are shown in Table 2. Amount of effluent treated by the plant is around 400 m^3 day^{-1}. During the treatment program, the samples were regularly collected at regular intervals from the outlet of aeration tank and analyzed for pH, BOD, COD, TSS, Oil and grease. Other monitoring parameters include MLSS, DO, NH_3-N, P and SVI. All the parameters were analyzed using by following standard methods of water and wastewater, APHA, AWWA (1998).

All the necessary chemicals obtained from E. Merck India Limited, Mumbai, India. The pH of the solution was measured with a EUTECH 5500 touch Screen pH meter (EUTECH Company, Singapore) using Field Effect Transistor (FET) electrode calibrated with standard buffer solutions. DR-4000 UV-VIS spectrophotometer (Hach Company, USA) was used for TSS, Oil and grease, NH_3-N and P determination. BOD trak reactor (Hach Company, USA) was used BOD determination. COD digester (Hach Company, USA) and DR-4000 UV-VIS spectrophotometer (Hach Company, USA) were used for COD determination. Dissolved Onygen (DO) of the solution was measured with a EUTECH 1500 DO meter (EUTECH Company, Singapore).

Augment P5 was obtained from Asianol Specialty Chemicals, India. The features of Augment P5 are shown in Table 3.

Augment P5 contains a special mixture of selectively adapted bacteria designed to degrade typical contaminants arising during dyeing, finishing, and bleaching in textile chemical industries.

RESULTS AND DISCUSSION

Most of the wastewater treatment plants are faced with increasing organic contaminants particularly due to increased production pressure and shrinking discharge limits. Often the existing microbiological treatment cannot handle these operating changes. Ever increasing organics, metals and solids loading, many of them are constantly prone to upsets and carryover in a biological treatment process. System upgrades or expansion are one answer to keep the plant in compliance but represent a major capital investment.

Bio-augment is a cost effective alternative. It enables plants to meet discharge limits with existing treatment facilities, while minimizing capital expenditures by reducing or eliminating surcharges and fines (Bhattacharya and Mandal, 2005).

In biological treatment, the record of degradable organics involves a sequence of steps including mass transfer, operation like absorption and the Bio-chemical enzymatic reactions. The activated sludge process, so named because it is involved in the development of an activated mass of microorganisms, which are capable of stabilizing a waste aerobically. The basic equation is:

Table 4: Dosing schedule for Augment P5

Days	Dosage (kg day^{-1})	Dosing place
Day 1 and 2	1.50	Each day at aeration tank inlet
Day 3 and 4	1.00	
Day 5 to 10	0.70	
Day 11 to 21	0.40	
Day 21 onwards	0.15	

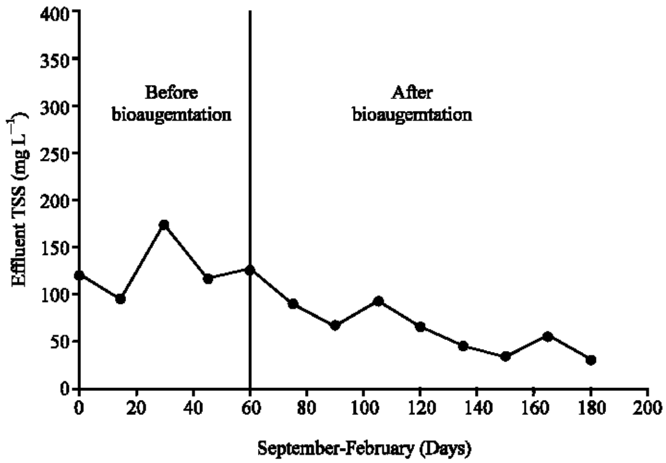

Fig. 2: Effluent TSS during September-February, before and after bioaugmentation

$$C, H, N, O, S + \text{Bacteria} + O_2 \xrightarrow{NH_3/PO_4} CO_2 + H_2O + \text{New cells*}$$

*New cells require C, H, O, N and P for growth.

The aerobic environment is maintained by diffused or mechanical aeration.

After a certain time interval, the mixture of old and new cells is passed into a settling tank where the cells are separated from wastewater. A part of the settled cells is recycled to aeration tank to maintain the desired MLSS value. The amount of cells recycled and the portion wasted depend on the desired treatment efficiency and other considerations related to growth kinetics.

Two distinct metabolic processes accomplish the bio degradation of waste by the microorganism → Respiration and Synthesis.

Depending on the objectives of the program (say type of problem present in the existing system) positive results are usually seen within a minimum of two to four weeks of the initial date of product application. Typically, hydraulic and solids retention, contaminants loading and other operating parameters play a key role in determining the time period required to obtain desired results by achieving a significant population density. The addition schedule requires heavy dosages initially to establish a sizeable seed population followed by maintenance dosages (Table 4).

Bacterial and enzymes generally perform within a pH range of 6.0-8.5 with the optimum pH near 7.0. Temperature affects the activity of the working solution. Optimum temperature range is 12-45°C. Activity drops significantly when temperature reaches beyond 50°C (Table 5).

The effect of implementation of Augment P-5 for textile mill wastewater degradation is shown in Fig. 2-5.

The results indicated that during the treatment period of 2-3 weeks of time it acclimatized with the existing bugs in the aeration tank. After three weeks it established its own environment for functioning effectively. The percent reduction in BOD value after 60 days improved significantly and

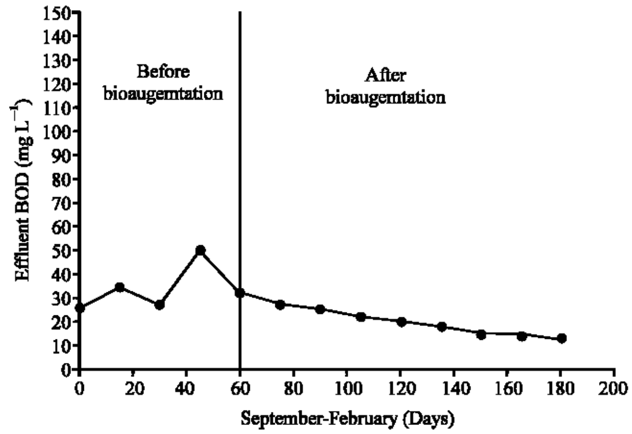

Fig. 3: Effluent BOD during September-February, before and after bioaugmentation

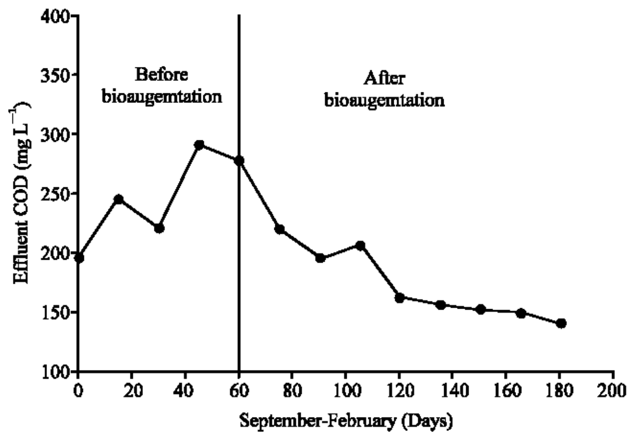

Fig. 4: Effluent COD during September-February, before and after bioaugmentation

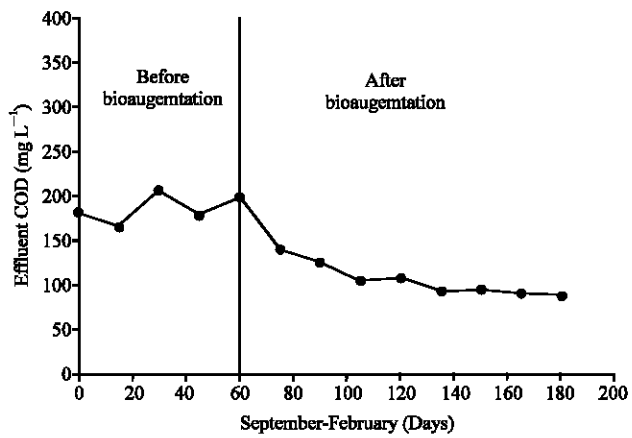

Fig. 5: Effluent SVI during September-February, before and after bioaugmentation

Table 5: Monitoring Parameters during Bio-augmentation program with Augment P5

MLSS	1800-2500
DO	1-1.4 (mg L^{-1})
NH_3-N	1.0 (mg L^{-1}) residual
P	1.0-1.2 (mg L^{-1}) residual
pH	7.2-7.8
SVI	145-70

reached to around 45-52% in system efficiency after 90 days compared to the value obtained when the bugs present before starting of bio-augmentation process. System efficiency improvement of more than 47% was observed during the removal of COD from wastewater. While in case of removal of TSS, this observed value for enhancement in system efficiency was above 53%. It is important to note that pH of bulk water does not change significantly during the period. Better sludge settling capacity of the plant also observed after starting up of Bio-augmentation process with Augment P5. The phenomenon of sludge settling characteristics is expressed in terms of Sludge Volume Index (SVI) and results shown in Fig. 5. Low SVI indicates compactness of the sludge with better effluent quality.

CONCLUSIONS

The above studies revealed that Bio-augmentation Technology can affectively be applied in conventional biological waste management system in textile mills for better reduction of parameter like COD, BOD, TSS from wastewater. It enables the removal of emulsifiers, detergents, dyeing agents and other aromatics (contributing to COD and BOD) from wastewater emanating from the textile plants. It also acts very efficiently during system reseeding, start-up operation of a biological treatment unit of a wastewater treatment plant. Apart from textile industry, Bio-augmentation technology can be applied for the waste water degradation from industries like tanneries, distilleries, pulp and paper units, sewage, steel making (coke plants), food processing industries, dairies, chemical process industries and refineries etc. It facilitates the removal of high organics loads, odor problems, sulphur related problems, fats, oils and greases in a cost effective way without making any capital expenditure.

Properly engineered and maintained bio-augmentation process can give the following benefits: Improve maximum rates of organic removal as measured by BOD and COD reduction.

- Provides higher growth and utilization rates in response to organic overloads for greater stability.
- Reduce sulphide related odor and improved foam control.
- Reseed a system after complete upsets (usually in to half the time of natural bacteria).
- Ready to supply of the required micro-organisms.
- educe sludge volume by improving system operation at lower sludge ages.
- Increase system stability with faster response to system upsets.
- Provides ability to degrade a broad spectrum of recalcitrant industrial chemicals.
- Finally helps to avoid any capital investment.

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