APPLICATION OF BIOREMEDIATION PROCESS FOR TEXTILE WASTEWATER TREATMENT USING PILOT PLANT

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ABSTRACT

Textile industry is considered as one of the largest generators of toxic chemical wastewater in Malaysia. Textile industries consume large volumes of water and chemicals for wet processing. Considering both volume discharged and effluent composition, the wastewater generated by the textile industry is rated as the most polluting among all industrial sectors . The control of this wastewater has become of increasing importance in recent years. Tightening regulation coupled with increased enforcement is forcing textile industries to treat their waste effluent to an increasingly high standard. The aim of the project is to apply the developed wastewater bioremediation processes in a pilot integrated system for treatment of textile wastewater to achieve an effluent that meets the Malaysian emission standard and to obtain a process with small footprint, low chemical requirement, and minimal chemical sludge generation and with potential water reuse to achieve sustainable, cleaner production. The prototype treatment system consists of four major components which is the pretreatment process, bio-treatment process, polishing process and bio-sludge treatment process. Results showed that an average removal of 98% COD, 92% of color 98.8% of NH_3-N and 89% of TSS from the wastewater was achieved by the integrated prototype treatment system.

Keywords: *bioremediation, textile wastewater, anaerobic-aerobic treatment, biosorption.*

INTRODUCTION

The textile industry uses large amounts of water in its preparation and dyeing processes. With more than 200 textile factories in Malaysia, the industry is a major source of wastewater [1] and textile industry wastewater accounts for 22% of the total volume of industrial wastewater produced in Malaysia. Textile wastewater is generally characterized as highly colored, with high concentrations of BOD, COD, total organic carbon (TOC) and dissolved solids. The strong color is due to persistent organics plus a variety of other pollutants, including chloride, ammonia, organic nitrogen, nitrate, sulphate , phosphate and heavy metals such as Fe, Zn, Cu and Pb. Azo dyes, which account for the majority of synthetic dyes have been widely used in textile dyeing industries because of its cost effectiveness in synthesis, firmness and variations in color compared to natural dyes [2]. During textile processing, inefficiencies in dyeing may result in large amounts of dyestuff being lost to wastewater, ending up in the environment [3]. The dyes are designed to be stable, thus are resistant to the microbial and physiochemical attack, and therefore, difficult to eliminate.

The biological treatment of anaerobic-aerobic process and fluidized bed process developed from the previous studies show great promise to be applied to the Malaysian textile industry wastewaters. This is particularly so as in Malaysia each factory treats its own wastewater and discharges effluent to a drain and not to a centralized treatment system. This means that the removal efficiencies are required, and would be more so once the proposed amendment to permissible limit, to include color as parameter, comes into force. The present treatment practice at most textile plants cannot meet the discharge limit, besides generating a lot of toxic sludges. The combination of anaerobic-aerobic filter developed at UPM and the SBBR developed at UKM would provide both reducing and oxidizing conditions and are able to handle the effluent variations common to textile mills.

Treatment of the wastewater using the combination of anaerobic-aerobic filter in principle involved indigenous microorganisms and selected dye-degraders (bioaugmentated microorganisms) in the form of biofilm. Biofilm consists of extracellular polymeric substances (EPS) produced by microorganisms upon growth on the solid surfaces (support materials *provided) in aqueous environment. They may consist of highly hydrated capsules attached to the cells. EPS may constitute the biofilm matrix and those released into the culture medium (free or unbound EPS).*

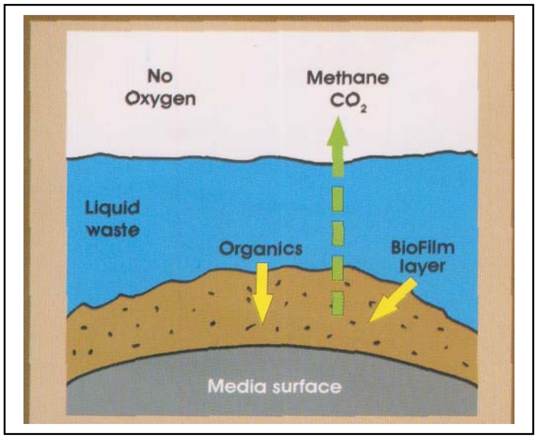

*Figure **1**: Anaerobic Process*

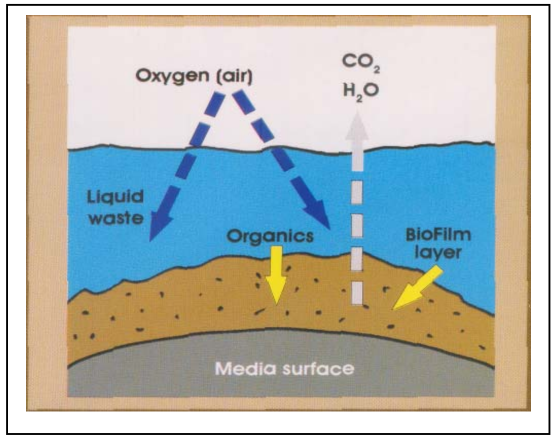

*Figure **2**: Aerobic process*

Bacterial decolourization of azo dyes could either be due to azo reduction and/ or desulphonation. The disappearance of colour was due to the reductive cleavage of azo bond(s) which is catalysed by enzymes such as flavin reductase and quinone reductase [4]. For decolourization of sulphonated azo dyes, the release of the sulphonic group may be required to decolourise the azo bond since desulphonation results in the destabilization of the benzene ring structure [5].

MATERIALS AND METHODS

2.1 The wastewater

The wastewater was pumped batchwise to the collection sump basin of the prototype treatment system. This basin was used as a mixing tank where the pH of wastewater was adjusted to pH 6 – 7.8 by using H_2SO_4 and lime under controlled temperature of 35 to 40^oC. The effluent was derived from the bleaching and scouring (on average 2m^3/day, COD of 200 to 5000mg/L) and dyeing processes (on average 2m^3/day, COD of 200 to 3000mg/L). The intensity of color of the wastewater ranges from 180 – 880 PtCo units. Other pollutants in the textile wastewater include TSS, VSS and NH_3-N. In terms of acidity, the wastewater was either very acidic (pH 3.9) or very alkaline (pH 11.4). With the high load of pollutants, efficient treatment is highly desirable before the wastewater can be discharged. The concentrations of COD, salts (especially sodium-sulfate) and pH in the different streams varied as well as the flows, especially in the wastewater from the dyeing processes. The main compounds in the combined bleaching and scouring effluent were Na_2CO_3, starch, polyvinyl alcohol, carboxyl-methyl cellulose, detergents, dispersing agents, sulfate and degreasing agents [6]. The characteristics of the wastewater in this basin largely varied (Table 1).

Table 1: Characteristics of wastewater in the collection sump basin.

Parameter	Raw textile wastewater	Standard A, EQ (SIE)R 1979
pH	9.1 – 9.5	5.5 – 9.0
COD (mg/L)	200 – 5000	50
TSS (mg/L)	55 – 2500	< 20
VSS (mg/L)	10 – 100	< 20
NH_3-N (mg/L)	0.2 – 9.5	-
Color (Pt/Co)	180 – 830	-

As shown by the Table 1, the COD levels are well above the emission limits set by the Environmental Quality Sewage and Industrial Effluent Regulation 1979 or the EQ(SIE)R 1979, and the color is far above the proposed amended level for the EQ(SIE)R 1979. Therefore, the textile wastewater is detrimental to the aquatic ecosystem if discharged untreated to the receiving water bodies.

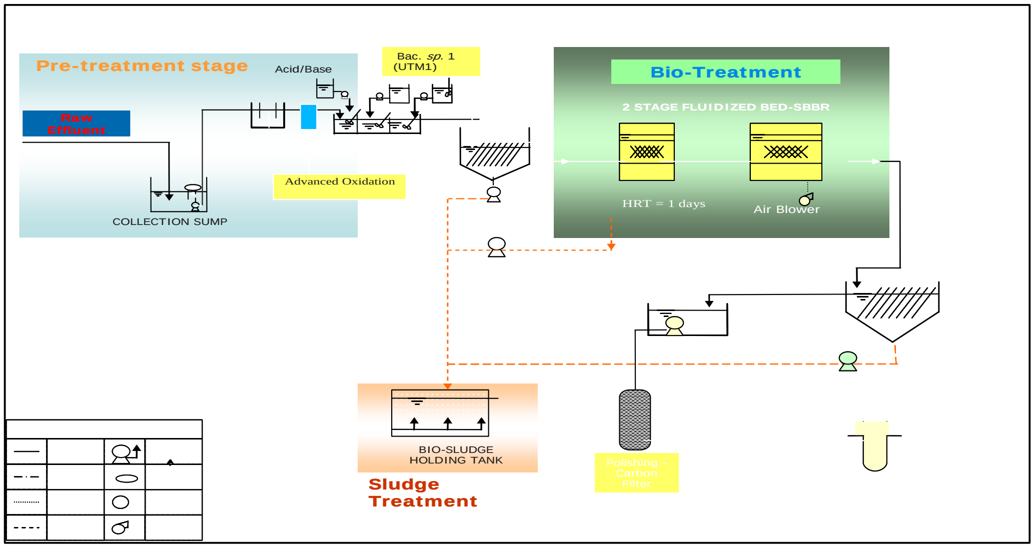

Figure 3: Schematic diagram of a pilot treatment system

2.2 Wastewater treatment plant

The prototype treatment system consists of four major components which is the pretreatment process, bio-treatment process, polishing process and bio-sludge treatment process. In the pretreatment process, the wastewater is pumped into a $2m^3$ of collection sump tank. Then, the wastewater will flow through the oil and grease trap, and finally through nutrient and pH mixing tank where the neutralization process of wastewater is being carried out. In the bio-treatment stage there are two reactors namely Advanced Fluidized Bed Reactor (AFBR) and Sequencing Batch Biofilm Reactor (SBBR) complete with aeration devices which are capable of treating high strength of wastewater. Both reactors were filled with cosmo (HDPE) balls to enhance the concentration of biomass through entrapment in the macrostructure. The Cosmo balls used in the system had proven to be an effective carrier material which functioned as a separation device, thus limiting biomass being washed out. The water is re-circulated by means of a pipe to the inlet of the SBBR reactor and mixed with the influent from the mixing tank. At start-up, both reactors were seeded with microbial inoculums. The AFBR and SBBR reactors was continuously fed at the inlet flowrate of $2m^3$/day. The oxygen concentration was kept approximately 4mg/L by mean of continuous aeration. In the polishing process, the treated water pumped to a polishing filter. Bacteria and fungi are common microorganisms explored for their potential use in bioremediation of textile wastewater due to their ability to decolorize and metabolize dyes (McMullen *et.al.*, 2001). Bio-sludge treatment consists of bio-sludge holding tank which functions as a sludge pumping and sludge transfer process. The deteriorated bio-sludge could be reused. Treated wastewater is sent to the final clarifier before being discharged.

The wastewater of the collection sump basin, AFBR reactor and SBBR reactor were daily analyzed for pH, COD, NH_3-N, NH^{4+}, NH_3, DO, TSS, VSS and color. The intensity of color was measured in PtCo unit using a spectrophotometer (HACH DR2500, USA). COD, TSS and VSS were analyzed using standard methods (APHA, 1989).

2.3 Determination of mechanisms of bacterial decolourisation

A decolourization mechanism was determined via the molecular approach. Since decolourization of azo dyes by the selected bacteria may involve desulphonation and or azo reduction, primers of genes for desulphonation were used to amplify the bacterial genes. This involved amplification of two genes (IsfA and ssuD) for enzyme synthesis of aromatic sulphonates degradation. For this purpose, genomic DNA of the bacteria was extracted using Promega Wizard Genomic DNA purification kit. The genomic DNA and suitable primers were used for the amplification of the desired gene. Polymerase chain reaction (PCR) was performed for 25 cycles, 94^{o}C for 1 min.50^{o}C for 1 min. and 72^{o}C for 2 min. PCR products were observed by agarose electrophoresis.

During the decolorization process, dyes undergo partial degradation to produce sulphanilic acid under anaerobic (conditions not strict but facultative anaerobic condition). Presence of sulphanilic acid produced is indicative of reductive cleavage of the azo bonds. In our study presence of sulphanilic acid, an aromatic amine was detected using HPLC (High Performance Liquid Chromatography; conditions: Water Hypersil C18, mobile phase, methanol: phosphoric acid). Sulphanilic acid was extracted from the treated textile using ethyl acetate.

Figure 4: Integrated of pilot treatment system installed at Kim Fashion, Senawang.

RESULTS AND DISCUSSIONS

Analysis has been carried out to investigate the effectiveness of the pilot treatment system in treating the wastewater from Kim Fashion textile industry. The results are summarized in Table 2. In general, the characteristics of the wastewater greatly differ from one batch to another. The characteristics are influenced by factors such as the intensity of activity/operation, fabric and type of dyes used at the time of sampling,

*Table **2:** Highest Percentage reduction achieved in the treatment of prototype system.*

	AFBR	SBBR	Overall removal
COD	89.2	93	98
Color	80.2	84	93
NH3-N	96.2	84	98
TSS	99.4	98	98

The percentage removal efficiency of COD, color, TSS and NH_3-N was 98%, 93%, 98% and 98% respectively. The combined process has low hydraulic retention time, HRT, thus provide saving in reactor size and land area. The major mechanisms of color removal by the microbes may not be adsorption but other mechanisms such as bioconversion or degradation.

Determination of decolourisation mechanisms by PCR amplication started with the selection of microbes to determine their mechanisms of decolourisation via molecular probing. The amplication of the two genes, *IsfA* and *ssuD* yielded fragments of 700bp and 1400bp respectively from the bacteria. This might signify the possibility of desulphonation by the selected bacteria, which is related to decolourization of the sulphonated azo dyes.

*Table **3**: Viable cell count of AFBR*

Date	Viable counts (cfu/mL)
06/09/06	300 x 10^{14}
15/09/06	300 x 10^{14}
28/09/06	300 x 10^{14}
02/10/06	76 x 10^{12}
16/10/06	33 x 10^{11}
30/10/06	13 x 10^{11}
01/11/06	18 x 10^{11}
16/11/06	95 x 10^{11}

Under aerobic condition, bacteria oxidize the organic compounds found in the wastewater for cellular growth and cell maintenance. Anaerobic treatment accomplishes more than 70% color removal while aerobic treatment which follows removes the rest by 80%. The growth of bacterial culture in AFBR is good. This is evident from the viable counts in Table 3 besides turbidity readings using spectrophotometer methods which can be used as an indirect measurement of bacterial growth. These results may be implicated with the ability of bacteria to convert or transform partially degraded dye products using specific enzymes into metabolic intermediates which can enter their central metabolic and can further be used to obtain energy for cellular activities and growth of the microbes.

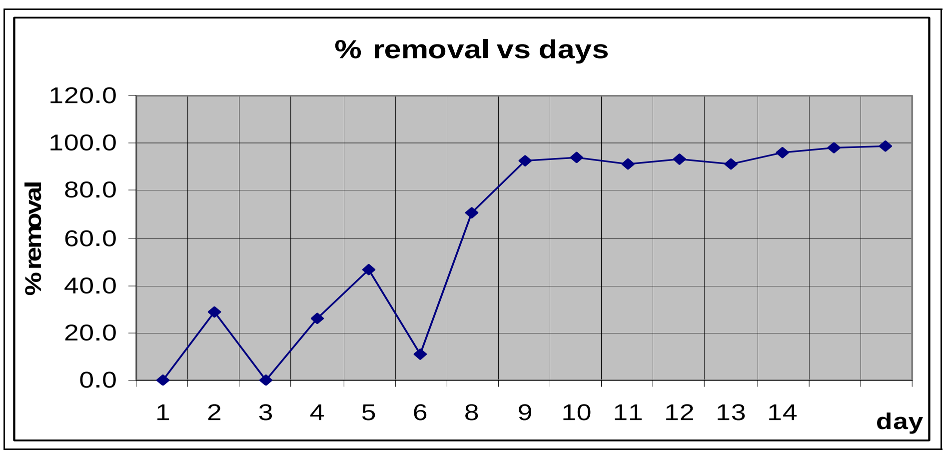

*Figure **5**: Percentage removal of COD*

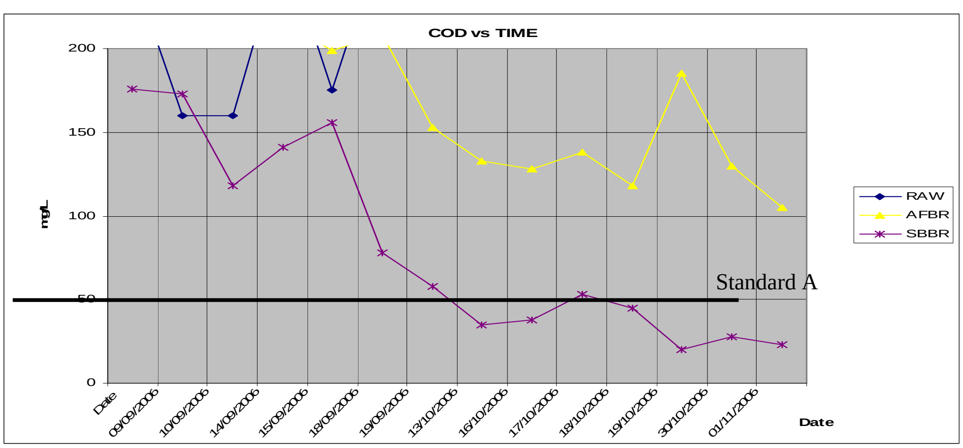

Figure 6: COD value achieved after final treatment

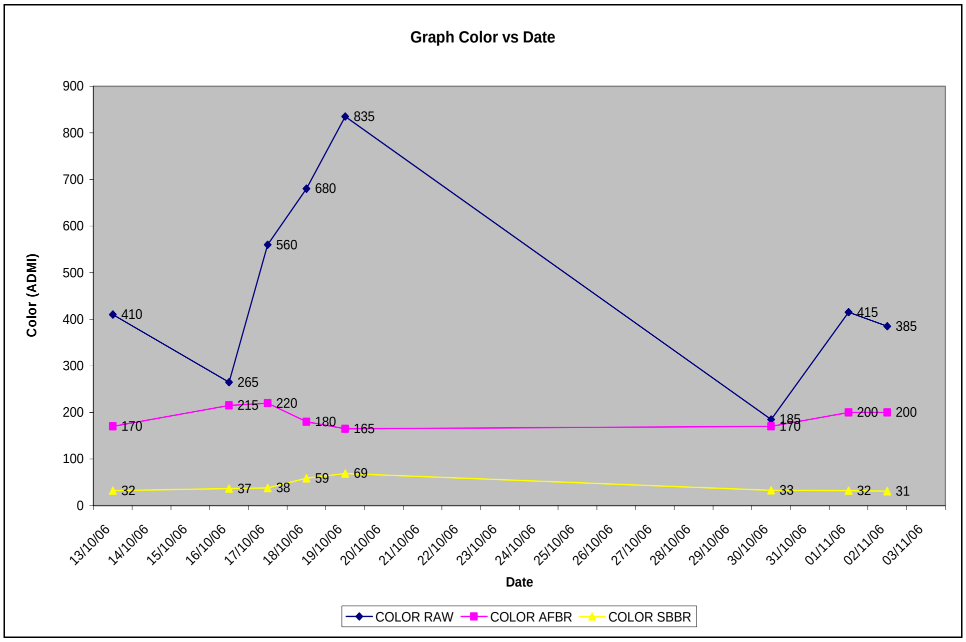

Figure 7: Color concentration vs day for overall treatment of textile wastewater

The COD percentage removal (Figure 5) of textile wastewater was up to 98%. The COD of raw wastewater were in the range of 200 to 1500 ppm. After the final treatment, the COD values were less than 100 ppm (Figure 6), meeting the discharge limits sets in the Environment EQ(SIE)R 1979.

The color removal (Figure 7) of textile wastewater was up to 93%. The total treatment gave very satisfactory colour removal with a change of dark reddish colour (835 ADMI) to clear effluent colour at less than 40 ADMI.

Table 4: Analytical laboratory results that compliance to DOE Standard A

Parameter	Standard A	Unit	Raw	AFBR	SBBR
Temperature	40	^oC	25	25	25
pH	6.0 - 9.0	-	7.38	9.15	8.30
BOD_5	20	mg/L	171	8	< 2
COD	50	mg/L	704	56	10
Chromium Hexavalent, Cr^{6-}	0.05	mg/L	< 0.01	0.02	< 0.01
Free Chlorine	1.0	mg/L	< 0.01	0.04	< 0.01
Phenol	0.001	mg/L	0.004	0.004	0.003
Sulphide	0.50	mg/L	1.86	< 0.3	< 0.3
Total Suspended Solids (TSS)	50	mg/L	644	26	6
Oil & Grease (O&G)	ND	mg/L	2	ND	ND
Cyanide	0.05	mg/L	< 0.01	0.04	< 0.01
Boron as B	0.005	mg/L	<0.005	0.04	0.01
Cadmium as Cd	0.001	mg/L	< 0.001	< 0.001	< 0.001
Copper as Cu	0.001	mg/L	0.15	0.07	< 0.001
Iron as Fe	0.002	mg/L	98.80	2.77	1.60
Lead as Pb	0.006	mg/L	0.04	0.03	0.01
Manganese as Mn	0.001	mg/L	0.29	0.03	< 0.001
Nickel as Ni	0.001	mg/L	0.01	< 0.001	< 0.001
Tin as Sn	0.007	mg/L	< 0.007	< 0.007	< 0.007
Zinc as Zn	0.002	mg/L	0.97	0.39	0.14
Arsenic as As	0.001	mg/L	< 0.001	< 0.001	< 0.001
Mercury as Hg	0.001	mg/L	< 0.001	< 0.001	< 0.001
Chromium Trivalent, Cr^{3+}	0.002	mg/L	0.03	< 0.002	< 0.002

Results presented in Table 4 show that all parameters analyzed for the final treated samples are in compliance to DOE Standard A. The final sample came out from the SBBR tank which form the last biological process in th system.

CONCLUSIONS

The scale up of laboratory bioreactor into a prototype treatment system was successful. The system was installed at Kim Fashion Sdn Bhd, Senawang showed promising results on removal of COD, ammonia nitrogen and color of textile wastewater to meet Malaysian effluent discharge limit Standard A. The removal of COD, color and NH_3-N acieevd in the pilot plant was up to 92%, 98% and 90% respectively.

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NOMENCLATURE

SBBR	Sequencing batch biofilm reactor
AFBR	Advanced fluidized bed reactor
PCR	Polymerase chain reaction
TOC	Total organic carbon
EPS	Extracellular polymeric substances
HPLC	High Performance Liquid Chromatography
DOE	Department of Environment