SUSTAINABLE MANAGEMENT OF TEXTILE WASTE WATER OF PAKISTAN

By

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ABSTRACT
Colour removal, especially from textile waste waters, has been a big challenge over the last decades, and upto now there is no single and economically attractive treatment that can effectively decolourise dyes. In the past years, notable achievements were made in the use of biotechnological applications to textile waste waters not only for colour removal but also for the complete mineralization of dyes. Different microorganisms such as aerobic and anaerobic bacteria, fungi and actinomycetes have been found to catalyse dye decolourisation. Moreover, promising results were obtained in accelerating dye decolourisation by adding various techniques. This paper provides a critical review on the current technologies available for decolourisation of textile waste waters and it suggests effective and economically attractive alternatives.

Nomenclature

Parameters	Abbreviations
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
TSS	Total Suspended Solids
TDS	Total Dissolved Solids

1-INTRODUCTION

Textile industry is the backbone of Pakistan economy and is one of the most important and largest industrial sectors of Pakistan with regard to production source of foreign exchange and labour employment. It alone accounts for 65% of the country's export, 46% of industrial production 38% of employed industrial work force and 9% of gross national product (Iqbal, et al., 2007).

With the increased demand for textile products, the textile industry and its waste water have been increasing proportionality, making it one of the main sources of severe pollution problems worldwide (Santos, et al., 2007).In particular, the release of dyes into waste waters by various industries is environmental issue due to various dyes' persistent and recalcitrant nature. Textile industries are responsible for the discharge of large quantities of dyes into natural waterways due to inefficiencies in dyeing techniques. Up to 50% of dyes may be lost directly into waterways when using reactive dyes (McMullan et al., 2001).

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The presence of dyes in waterways is easily detectable even when released in small concentrations. This is not only unsightly, but the colouration of the water by the dyes may have an inhibitory effect on photosynthesis affecting aquatic ecosystems. Dyes may also be problematic if they are broken down anaerobically in the sediment, as toxic amines are often produced due to incomplete degradation by bacteria. The breakdown products of dyes are toxic and mutagenic to life (Weisburger, 2002). Different figures showed the real picture of contamination.

Fig:1 Different out lets of Industrial Waste Water

The fibers used in the textile industries can be divided into two types: natural and man-made. The two major natural fibers are wool and cotton. The most important man-made fibers include polyester, rayon, nylon, polyacrylic and polyamide. It appears that most of the textile effluents do not have high BOD content, but they do have large pH and color variations. Besides, polyvinyl alcohol (PVA), starches and various surfactants may also appear in many dyeing waste effluents. These compounds are chemicals widely used in the dyeing and sizing operations. They have a high COD content of over 10,000 mg/1 and can contribute considerably to overall COD content of the textile waste effluents.

The normal dyeing operations of a textile plant are such that the dye used varies from day to day and sometimes even several times a day, primarily because of the batchwise nature of the dyeing process. Dye changes cause considerable variation in the waste characteristics, particularly pH. A large pH swing is especially troublesome primarily because the pH tolerance of conventional biological and chemical treatment systems is very limited. Hence without proper pH control, normal operation of these treatments is essentially impossible.

Along with the high pH variation, the textile waste effluents also have a relatively high temperature. In several steps of the dyeing operation, hot rinse waters of up to 90°C are used, resulting in a final effluent temperature between 35°C and 40°C. This necessitates proper heat dissipation of the hot effluent prior to other treatments.

Strong color is the component of the textile waste effluent which is the most difficult to treat, as mentioned earlier. The combination of strong color and high dissolved solid content leads to high turbidity of the waste effluent. The dyestuffs are highly structured polymers and very difficult to decompose biologically. Hence there is little decomposition of these molecules in the activated sludge process. A strong effluent color, if not removed, will cause considerable disturbance to the ecological system of the receiving waters. Depending on the sources, the dye waste effluent varies considerably in color, suspended solid content and COD concentration. The dye waste effluents varied in color from purple, dark red, brown, grey, dark blue or black.

1.1- PROCESSING OF TEXTILE

Textile production involves a number of wet processes. Each process generates waste water containing different types of pollutants. Finishing and drying processes generate volatile organic compound. Dyeing and printing processes produce waste water-containing toxic organic compound such as phenols and also impart highly concentrated color and copper, chromium metals. Bleaching of fibers adds halogen, makes the waste water alkaline. Desizing step in textile process contributes 50 % increase of BOD load. Wool processing may release pathogenic germs. Sometimes pesticides are used for the preservation of natural fibers. These pesticides are discharged into waste water during washing and scouring process. Chemicals present in finishing waste water are highly variable due to the broad range of finishers available, which generate pollutants of natural and synthetic polymers. The biodegradable organic compound can cause deficiency of dissolved oxygen in receiving water bodies and have a direct effect on aquatic life (Dos Santos et al., 2006).

2- TREATMENT PROCESSES

In the following items we have tried to cover the physical, chemical and biological process for the treatment of waste water. It is worth to mention that this review gives the special attention to waste water treatment by physical, chemical and biological process.

2.1-BIOLOGICAL TREATMENT

2.1.1 BACTERIA

From the textile effluent different aromatic compounds are produced and these are susceptible to biological degradation under aerobic and anaerobic conditions. Under aerobic conditions, the enzymes mono-and di-oxygenates catalyze the incorporation of oxygen from O_2 into the aromatic ring of organic compounds prior to ring fission (Madigan et al., 2003). Although azo dyes are aromatic compounds, their substituents containing mainly nitro and sulfonic groups, are quite recalcitrant to aerobic bacterial degradation (Claus et al., 2002). This fact is probably related either to the electron-withdrawing nature of the azo bond and their resistance to oxygenases attack, or because oxygen is a more effective electron acceptor, therefore having more preference for reducing equivalents than the azo dye (Chung et al., 1993). However, in the presence of specific oxygen-catalysed enzymes called azo reductases, some aerobic bacteria are able to reduce azo compounds and produce aromatic amines.

2.1.2-FUNGI

The capacity of fungi to reduce azo dyes is related to the formation of exoenzymes such as peroxidases and phenoloxidases. Peroxidases are hemoproteins that catalyse reactions in the presence of hydrogen peroxide (Duran et al., 2002). Lignin and manganese peroxidases have a similar reaction mechanism that starts with the enzyme oxidation by H_2O_2 to an oxidized state during their catalytic cycle. Afterwards, in a mechanism involving two successive electron transfers, substrates such as azo dyes reduce the enzyme to its original form (Stolz, 2001). Eighteen fungal strains able to degrade lignocellulosic material or lignin derivatives were tested with the azo dyes.

2.1.3-ENZYME TECHNOLOGY

Laccase are copper-containing enzymes that have very broad substrate specificity with respect to electron donors, e.g. dyes (Abadulla et al., 2000). However, despite the fact that laccases from T. versicolor, Polyporus pinisitus and Myceliophthora thermophila were found to decolourise anthraquinone and indigoid-based dyes at high rates, the azo dye, Direct Red 29 (Congo Red) was a very poor substrate for laccases (Claus et al., 2002). Chivukula and Renganathan (1995) cited that the azo dye must be electron-rich to be susceptible to oxidation by laccase of Pyricularia oryzae. This situation is suitable for the generation of a phenoxy radical, with consequent azo bond cleavage, and the release of molecular nitrogen. The addition of redox mediators has been shown to further extend the substrate specificity of laccases with regard to several dye classes, although redox mediators can also be formed from laccase oxidation of phenolic azo dyes (Claus et al., 2002). The complete flow sheet of waste water treatment plant is shown Fig-2.

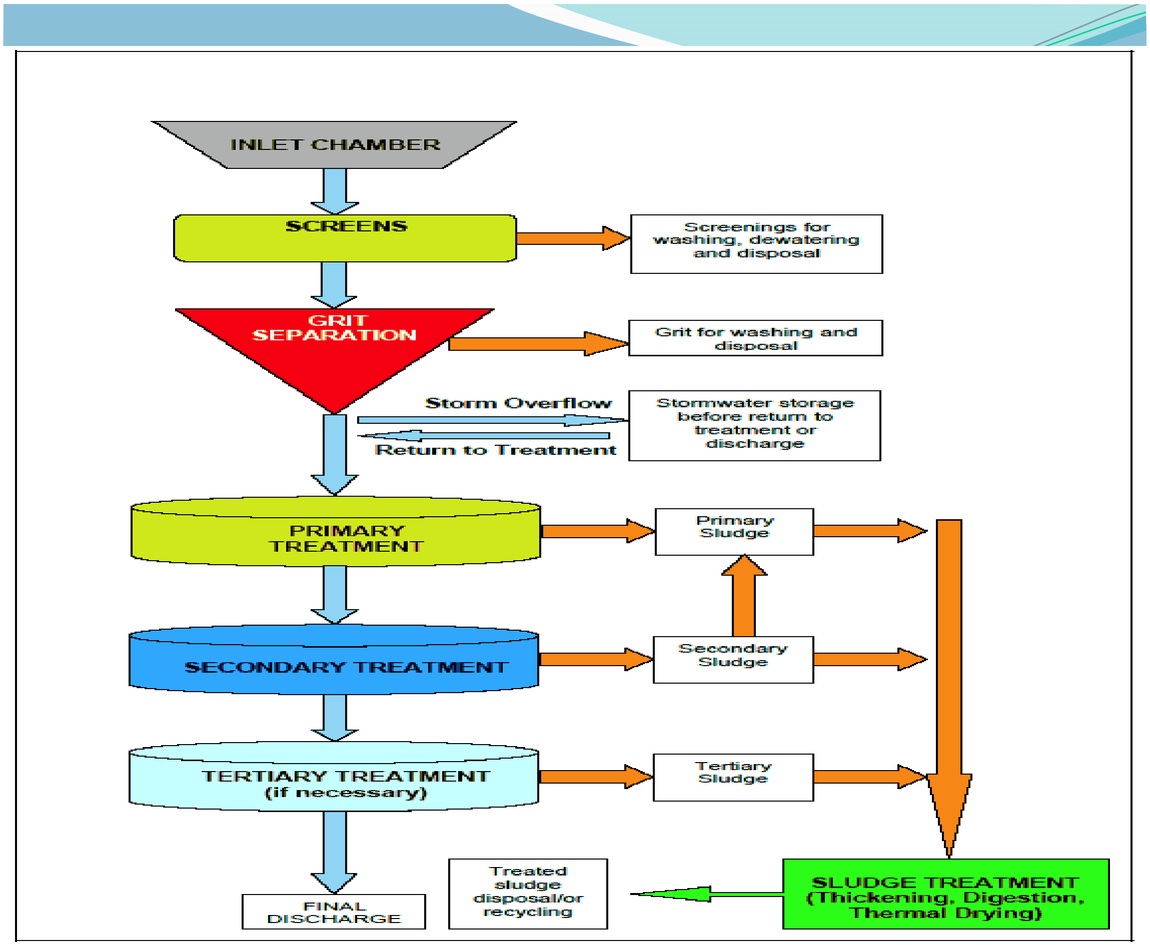

Fig:2: Flow sheet of waste water treatment plant

2.1.4 -ACTIVATED SLUDGE REACTOR MODEL

2.1.4.1-Feeding tank

30 liters capacity plastic drum with an outlet fixed at 3 mm above its bottom to stop the flow of solid to the aeration tank. There is a plastic tube to ensure proper and regular supply of untreated settled waste water from feeding tank to aeration tank.

2.1.4.2-Pinching cock

It regulates the flow of settled waste water into an aeration tank, and is installed on the plastic tube.

2.1.4.3-Air pump

This pump provides sufficient supply of oxygen not only to meet biological oxygen requirements but also to keep suspended solids and activated sludge in suspension. It also helps to contact between microbes and organic matter which is necessary for efficient treatment of waste water.

2.1.4.4-Aeration tank

It is simple locally fabricated plastic tank of dimension 20 cm x 15 cm x 29 cm. Working depth of aeration unit was maintained 17.5 cm. The working volume *was* 6.5 liter. The diffuser was placed at a depth of 25-50 mm above the bottom of tank.

2.1.4.5-Final Clarifier

The final clarifier is separated from aeration tank by a glass plate, which acts as a weir to discharge flows to the final clarifier. The size of clarifier is 15 cm x 10 cm x 29 cm. (Fig-2)

2.1.5-TREATMENT OF WASTE WATER BY ACTIVATED SLUDGE REACTOR

During study, the conventional activated sludge rector reduced the BOD_5 and COD contents of the effluents to the limits in the NEQS in about 10 days retention time. The main reason to take longer time to treat the waste water may be due to inherent disability of microbes to break down the dyes rapidly. Dyes are complex organic matter that requires long time to decompose by microbes. Dyes colour also limits the penetration of light hence hindering microbial growth and activities. To overcome these problems it is common practice to pre – treat textile waste water either by using coagulants or adsorption techniques before biological treatment (Lina *et al*., 2006). Activated carbon, Sand, and Brick power were used as absorbents to treat the textile waste water. Table-1 shows the removal efficiency of activated carbon. It removes the dyes colour of sample due to great absorption capacity. Activated carbon proved a very good material to treat the waste water. The average BOD_5 and COD removal percentage was 63% and 59% respectively. Total solids such as TDS and TSS average content were found to be reduced to 44% and 41% respectively. Treated carbon also resulted in 10% reduction in the $P^{H.}$ Activated carbon was very effective to remove BOD_5 and COD contents and could not be cost effective. (Turan, 2001).

Table-1. Performance of Activated Carbon

Parameters	Sample No 1			Sample No 2		
	Influent	Effluent	Removal %	Influent	Effluent	Removal%
P^H	10.5	9.6	8.6	10.8	9.7	10
$TempC^0$	38	25	--	40	30	--
BOD_5	588	223	62	640	230	64
COD	1528	627	59	1556	622	60
TDS	4250	2423	43	4560	2508	45
TSS	320	195	39	370	155	42

(Iqbal et al., 2007)

2.1.5.1-BIOLOGICAL TREATMENT OF WASTE WATER PRE-TREATED WITH ACTIVATED CARBON

Presence of dyes in the textile waste water was found to be major hindrance in the growth of bacteria because of their characteristics such as colour and toxicity. However waste water treated with activated carbon appeared to be almost transparent, hence promoted the growth of the bacteria. Consequently, the efficiency of biological treatment was significantly enhanced. It was noted that activated carbon acted as a good absorbent for dyes compounds as well.

Table-2. Biological treatment of waste water pre-treated with Activated carbon

R.T(days)	BOD_5 (mg/l)			COD (mg/l)		
	Influent	Effluent	Removal %	Influent	Effluent	Removal%
2	223	134	77.2	627	389	74
4	223	78	87.2	627	232	85
6	223	49	92	627	144	90

(Iqbal et al., 2007) R.T= Retention Time

Table-2 indicates that four days retention time resulted in more than 87% removal of BOD_5 . It is apparent from the results that six days retention time has lowered the BOD_5 content to half of the limits provided in the NEQS. It is important to mention that biological treatment of waste water pretreated with activated carbon was resulted in 50% reduction in retention time and 27% increase in the removal efficiency of biological process, when compared with the results of biological treatment of untreated waste water. (Lina *et al.*, 2006).

2.2-PHYSICAL TREATMENT

2.2.1-PERFORMANCE OF SAND

The efficiency of sand filter in treating textile waste water was not appeared to be significant as evident in table-3. The average removal of BOD_5 and COD content was found to be 34% and 32% respectively. For TDS and TSS the average removal varied from 12.5% and 30%. Since sand as absorbent material was not found to be efficient. It was inferred that biological treatment of effluent pretreated sand was not feasible. (Turan, 2001).

Table-3. Performance of Sand

Parameters	Sample No 1			Sample No 2		
	Influent	Effluent	Removal %	Influent	Effluent	Removal%
P^H	10.5	10.3	1.9	10.8	10.5	2.7
$TempC^0$	38	22	--	40	28	--
BOD_5	588	382	35	640	429	33
COD	1528	1024	33	1556	1089	30
TDS	4250	3612	15	4560	4104	10
TSS	320	224	30	370	157	30

(Iqbal et al., 2007)

2.3-CHEMICAL TREATMENT

2.3.1- TREATMENT OF WASTE WATER WITH LIME

The commercial lime was used as coagulant for waste water treatment, which reduced the pollution loads significantly. A dose of 1.5 g/l of lime at pH 6.0 gave optimal results. Analysis results are represented in table 4. Average removal of BOD_5 was 66% where as COD reduction was found to be 65%. Lime treatment reduced the TDS and TSS content to 56% and 60% respectively. It was inferred from the results that treatment with lime was effective and cheaper when compared with activated carbon. Apparently, there were some inherent problems with lime treatment. It increased the pH of waste water. Temperature of waste water was also increased due to exothermic reaction of lime with water. However, such artifacts were not serious and could be addressed easily. (Helal Uddin *et al*., 2003).

Table-4. : Pretreatment with commercial lime after sedimentation results

	Sample No 1 (mg/l)			Sample No 2 (mg/l)		
Parameters	Influent	Effluent	Removal %	Influent	Effluent	Removal%
P^H	6	9.0	--	11	12.7	--
$TempC^0$	37	55	--	38	57	--
BOD	662	238	64	675	209	69
COD	1582	585	63	1625	537	67
TDS	4650	2558	45	5030	2346	53
TSS	380	232	39	420	244	42

(Iqbal et al., 2007)

It was also apparent from the results that lime, though reduced the pollution loads significantly, it could not bring the concentration of BOD_5 and COD to the limits given in the National Environmental Quality Standards.

2.3.2-BIOLOGICAL TREATMENT OF WASTE WATER PRE-TREATED WITH LIME

Analysis results of biological treatment of waste water pre-treated with lime are given in table 5. The biological treatment process in conjunction with chemical treatment showed remarkable reduction in retention time and removal of BOD_5 and COD content of effluent. A 25% less retention time, when compared with the results of biological treatment of waste water pre-treated with activated carbon, gave 88% and 86% removal of BOD and COD content respectively. Whereas four days retention time resulted in 94% and 92% of BOD and COD loadings of the treatment effluent. (Aboulhassan *et al*., 2005 ; Shah *et al*., 2003).

Table-5. Biological treatment of waste water Pre-treated with lime

R.T(days)	BOD (mg/l)			COD (mg/l)		
	Influent	Effluent	Removal %	Influent	Effluent	Removal%
2	238	131	80	585	310	80
3	209	77	88	537	220	86
4	209	38	94	537	124	92

(Iqbal et al., 2007)

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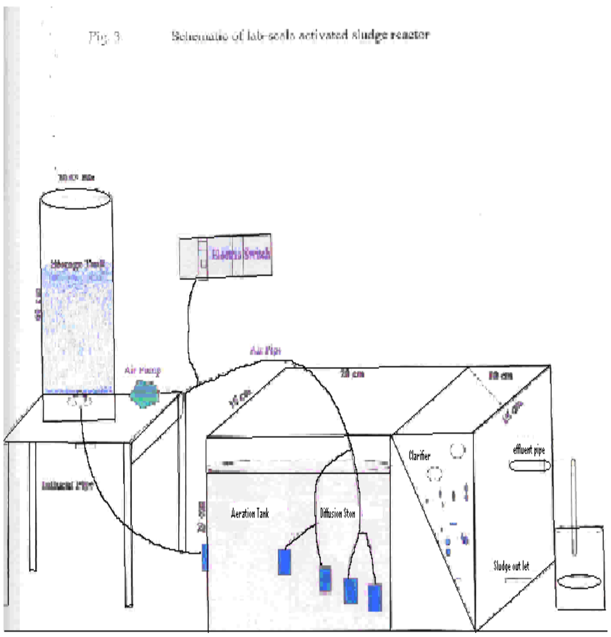

Fig.-3. Lab Scale Activated Sludge Rector Mode

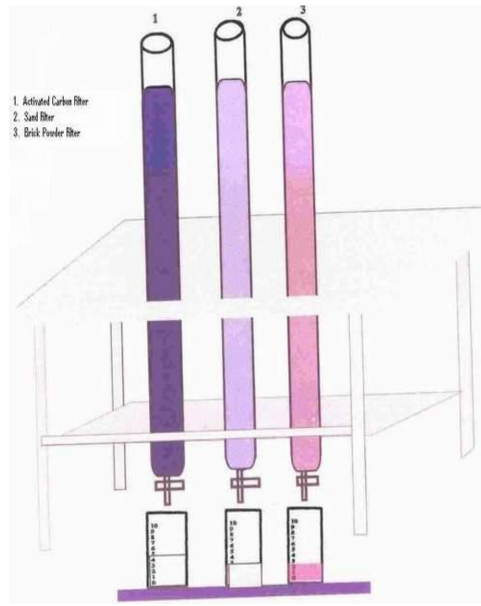

Fig.-4. Absorption Columns

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