Rethinking Environmental Friendly Technology for Sustainability in Bangladesh

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Abstract— Most of the textile industry discharges the polluted textile waste-water directly into the waterways as the cost of treatment process is high. To minimize the cost, an effective and advanced treatment process has been setup at Mascom Composite Textile Ltd and Dalas Fashion Ltd. at Gazipur, Dhaka. The treatment process consists of a combined process (anaerobic and bio-filtration process) which is mentioned as High Rate Biological Treatment (HRBT) process. This biological treatment process is successfully operating without chemical process. The raw textile waste-water is highly polluted with high level of alkalinity in nature. The pollution parameters were removed successfully with standard quality by using the HRBT process. The ETP treatment capacity was 50,000 Liter/hour. Case study on chemical ETP process has revealed that taka 8.984 million is required for chemical ETP whereas taka 1.784 million for HRBT ETP process. Thus HRBT ETP process has been proved to be highly economical than the Chemical ETP process.

Index Terms: Sustainability, Chemical oxygen demand, HRBT, ETP, RCL, optimizing effluent generation, COD, BOD

I. INTRODUCTION

Most of urban areas in Bangladesh are facing severe long-term aquatic environmental pollution primarily caused by direct discharge of liquid of Textile wastewater in the waterways. High organic loaded wastewater creates environmental pollution. As a result most particularly in the vicinity of urban areas rivers around Dhaka city are found to be severely polluted in Dhaka city. In Bangladesh, there are very few wastewater treatment facilities; mainly due to high costs of treatment. The result is severe water pollution in the Dhaka city, even more during dry season when all rivers become severely polluted. The textile wastewater is a serious environmental challenge faced by Bangladesh textile sub sector. A scenario of direct discharge of textile wastewater to the environment is shown in Figure-1.

Fig-1: Direct Discharge of Textile polluted wastewater to the Environment

The textile wastewater contains organic compounds and synthetic chemicals. Certain chemicals which are used in the textile industry cause environmental or health problems. Due to presence of chemicals, it causes instance

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allergic skin reaction or even causes cancer. The major raw material for textile processing is grey fabric and most of materials consist of cotton and blended fabric. Textile processing employs a variety of chemicals depending on the nature of raw material and products such as; enzymes, detergents, dyes, acids, soda and salt. The textile wastewater is a highly polluted in terms of organic matter and suspended matter such as fibers, grease and chemicals. The textile wastewater is usually hot and alkaline with strong offensive smell and color due to use of dyes and chemicals. Some studies showed that wastewater from textile industry are highly toxic and has inhibitory effects on an activated sludge and nitrification. In the textile wastewater situated with high values of chemical oxygen demand (COD) and biological oxygen demand (BOD).

Most of the developing countries did not maintain any treatment process for wastewater and some of the countries just follow the traditional methods such as stabilizing ponds for wastewater treatment without applying the treatment process (de Sousa *et al.*, 1996). Stabilizing pond takes very long time, extensive land area is required, spread a serious noxious smell and affects the air pollution, creates the potential breeding field for mosquitoes which affect seriously the public health and spreads diseases. The Up-flow Anaerobic Sludge Blanket (UASB) treatment system has been developed first time in Netherlands in 1970s (Lettinga and Vinken, 1980). Thereafter, the intensive use of UASB system has been developed for wastewater treatment over the past decades in developing countries in the tropical and subtropical regions such as Brazil, Colombia, China, India, and Mexico (Ciftci and Oztiirk 1995, Miah *et al.*, 2004). The high rate biological ETP is more popular, because;

i). It has high rate of anaerobic treatment capacity.
ii). Treatment efficiency well under mesophilic temperature condition,
iii). High organic strength wastewater can be treated,
iv). Relatively simple and low operation cost
v). High organic removal efficiency,
vi). Bio-energy benefit could be obtained through the biogas production and
vi). Excess sludge production is very low compared to conventional treatment process.

The major objectives of the study are as follows:

i). to compare the treatment efficiency of the Chemical and HRBT ETP
ii). to verify the cost effectiveness for Chemical and HRBT ETP
iii). Find out the recommended ETP process based on analysis

Methodology:

This paper is based on investigating selective factories equipped with different types of ETPs. Samples were collected from different sampling points of ETPs. Samples were analyzed for various physicochemical parameters like pH, total dissolved solids (TDS), total suspended solids (TSS), 5 days biochemical oxygen demand (BOD5), chemical oxygen demand (COD), Dissolved oxygen (DO) etc. This study includes test report of Environmental Engineering Laboratory (BUET), Department of Environment (DoE) and Department of Applied Chemistry & Chem. Tech. (DU). Suggestions of ETP executives, operators and designers are also included in this paper.

Sampling design and sampling size

The sampling design to be used for this survey is a three stage procedure. The first stage sampling unit is industry level the second stage unit is owner, and the third stage unit workers. Sampling size to be determined using the standard formula given below. Total sample size to be around 200.

$$\text{ss} = \frac{t^2 \times p(1-p)}{C^2}$$

ss = Sample size
t = t-value (e.g., 1.96 for a 95 percent confidence level)
p = Percentage of population picking a choice, expressed as decimal
C = Confidence interval, expressed as decimal (e.g., .04 = +/- 4 percentage points)

II. DATA COLLECTION

Data will be gathers by face to face interview using pre-tested structural questionnaire. To develop questionnaire focus group discussions will be required. The critical issues identified in the discussions will be translated into a series of questions to include in the questionnaire. This

ISSN 2229-5518

will take some time, with consideration of appropriate wording of questions (in Bangle). Care is also required to ensure that the questionnaire is not overlong. To ensure that the enumerations are fully familiar with the questions, and to check that the questions make sense to target group members, a pre-testing will be done.

Data analysis:

Descriptive data analysis:

In order to carry out descriptive analysis we will employ table, graph, ratio etc. This analysis will prepare foundation for empirical analysis.

1.1. Why biological treatment is the best method?

1. Economic perspective.
2. Efficiency perspective.
3. Ecological perspective.

1.2. Economic perspective: Effluent treatment with biological method is very cost-effective compared to other methods because of least operation and maintenance cost due to very low chemical consumption, low labor cost, less sludge treatment and disposal cost. It will be clearly realized by following comparative cost analysis tables.

Table 1: Tentative installation cost of ETPs : 60 m3/hour treatment capacity.

INSTALLATION COST				
Physico-chemical	1500 - 2000 sq ft	35 - 40 lac	20 - 25 lac	55 - 65 lac
Biological	4000 - 5000 sq ft	160 - 170 lac	140 - 150 lac	3 - 3.5 crore
Combined Bio-chemical	2000 - 2500 sq ft	40 - 50 lac	35 - 40 lac	75 - 90 lac
Chlorination	1500 – 2500 sq ft	20 - 25 lac	45 - 60 lac	65 - 85 lac

Courtesy: ETP Provider- TEXMAC (BANGLADESH) LIMITED.

Table 2: ETP recurring expenditure:

PROCESS	PEAK FLOW m3/hr	CHEMICALS	DOSING RATE kg/day	CONSUMPTION kg/m3	PRICE tk/kg	COST tk/m3	TOTAL tk/m3
Physico-Chemical 65 m3/hr		Lime	600 - 650	0.38 - 0.42	10 - 12	3.86 - 5.04	**15.5 - 22.5**
		1000 - 1200	0.64 - 0.77	14 - 16	8.97-12.32	1000 - 1200	
		Polyelectrolyte	8 - 10	0.005 - 0.01	260 - 280	1.33 - 2.80	
		H2SO4	250 - 300	0.16 - 0.19	8 - 12	1.28 - 2.28	
Biological	60 m3/hr	H2SO4 (98%)	150 - 200	0.10 - 0.139	8 - 12	0.83 - 1.6	**1.5 - 2.0**
		Polyelectrolyte	1.5 - 2	0.001 - 0.0013	260 - 300	0.27 - 0.36	
		Antifoam	occasional	-	200 - 250	-	
		Decolorant	occasional	-	95 - 100	-	
		Nutrient	occasional	-	150-300	-	

1.3. Efficiency perspective:

Efficiency of effluent treatment plant is estimated by the reduction percentage of BOD, COD, TSS,

ISSN 2229-5518

TDS, Color and other parameters like chloride, phosphorus, nitrogen, phenolic compounds etc. Biological effluent treatment plant is highly efficient. Table 4 exposes the comparative degree of efficiency of different active ETPs.

STANDARDIZATION:

Factory type	Composite textile industries.
ETP treatment capacity	55 - 150 m3/hour
Avg. Inlet BOD5 range	110 – 281 mg/l
Avg. Inlet COD range	284 – 480 mg/l
Avg. Inlet TSS range	62 – 276 mg/l
Avg. Inlet TDS range	240 – 4950 mg/l
Avg. Coagulant dose (FeSO4)	583 – 984 mg/l
Avg. Coagulant dose (Lime)	330 – 606 mg/l
Avg. Inlet PH	6.7 – 11.5
Avg. Inlet temperature	35 – 500C
Discharging area	Inland surface water.

List of testing parameters and equipments:

1. Biological oxygen demand (BOD5): Amount of dissolved oxygen consumed by sample of effluent incubated for five days at 20°C. (Winkler's method)

2. Chemical oxygen demand (COD): It is equal to the number of milligrams of oxygen that a liter of sample will absorb from a hot, acidic solution of potassium dichromate.
(Dichromate Reflux method).

3. Total dissolved solids (TDS): -By TDS meter.
- TDS can also be measured by filtration to remove suspended solids and then evaporation of the filtrate (remaining liquid portion, usually done at 105°C) to leave a solid residue which can be weighed.

4. Total suspended solids (TSS): A sample of wastewater is filtered through a standard filter and the mass of the residue is used to calculate TSS.

5. Dissolved oxygen (DO): By DO Meter & electrodes.

6. PH : - By PH paper.
- PH Meter: Calibrated pH meter probe is submerged in a sample of the effluent and after stirring gently for a few moments the pH meter should give a stable pH reading.

7. Temperature: By using thermometer calibrated in degree Celsius.

8. Mixed liquor suspended solids (MLSS): Filtration of the mixture of solids resulting from combining recycled sludge with influent wastewater in the bioreactor. The MLSS is the weight of the solid divided by the volume of sample.

9. Sludge volume index (SVI): Determined by placing a mixed-liquor sample in a 1 liter cylinder and measuring the settled volume (SV) after 30 minutes and dividing it by the corresponding sample's MLSS concentration.

10. Coagulation-flocculation: Jar test: FeSO4, Lime, Polyelectrolyte are poured into the 1 liter volume jar containing wastewater to identify required optimum dose.

Table 4: Performance analysis of active ETPs.

FACTS	UNIT	*STANDARD	BT	AT	RE %	BT	AT	RE %	BT	AT	RE %
BOD5	mg/l	50/150*	125	65	48	147	69	53.1	115	56	51.3
COD	mg/l	200	340	135	60.3	290	110	62.1	295	153	48.1
TSS	mg/l	150	170	62.9	63	276	80	71	210	53.88	74.3
TDS	mg/l	2100	1956	1795	8.2	1600	1820	-13.8	3045	2245	26.2
DO	mg/l	4.5 - 8	0	4.9	0	5.1	0	4.9	DO		
PH	-	6 - 9	11.5	8.6	11.2	7.3	10	7.72	PH		
TEMP	0c	40	37	29	41	30	40	29	TEMP		

BT-before treatment value, AT-after treatment value, RE(removal efficiency)= {(BT-AT)/BT}*100
*BOD limit of 150 mg/l implies only with physico-chemical processing.
*Bangladesh standard for wastewater discharge to inland surface water as per ECR 1997. It consists no standard for colour,so this parameter is not mentioned.

Table: 5

BIOLOGICAL											
FACTS	**UNIT**	**STANDARD**	**BT**	**AT**	**RE %**	**BT**	**AT**	**RE %**	**BT**	**AT**	**RE %**
BOD5	mg/l	50	110	29	73.6	145	19.45	86.6	281	23	91.8
COD	mg/l	200	320	128	60	304	102	66.4	356	174	51.1
TSS	mg/l	150	130	18	86.2	230	54	76.5	204	36	82.4
TDS	mg/l	2100	4950	2010	59.4	2492	1135	54.5	3200	1580	50.6
DO	mg/l	4.5 - 8	0	4.5	0	4.7	0.1	4.6			
PH	-	6 - 9	10.5	8.03	9.76	7.69	10.3	8.1			
TEMP	0c	40	41	35	43	34	50	35			

Table: 6

COMBINED CHEMICAL & BIOLOGICAL											
FACTS	**UNIT**	**STANDARD**	**BT**	**AT**	**RE %**	**BT**	**AT**	**RE %**	**BT**	**AT**	**RE %**
BOD5	mg/l	50	230	98	57.4	138	44	68.1	230	36	84.3
COD	mg/l	200	472	299	36.7	352	116	67	480	160	66.7
SS	mg/l	150	90	34	62.2	180	28	84.4	69	56.2	18.6
TDS	mg/l	2100	3210	2518	21.6	240	480	-100	727	1519	-108.9
DO	mg/l	4.5 - 8	0	6.8	0	4.4	0	8.5	**DO**		
PH	-	6 - 9	8.3	7.15	6.7	6.5	8.5	6.5	**PH**		
TEMP	0c	40	43	28	37	28	39	32	**TEMP**		
R CL	mg/l	-	0	3	0	2.95	0	3.5	**R CL**		

Table : 7

CHLORINATION											
FACTS	**UNIT**	**STANDARD**	**BT**	**AT**	**RE %**	**BT**	**AT**	**RE %**	**BT**	**AT**	**RE %**
BOD5	mg/l	50	230	98	57.4	138	44	68.1	230	36	84.3
COD	mg/l	200	472	299	36.7	352	116	67	480	160	66.7
TSS	mg/l	150	90	34	62.2	180	28	84.4	69	56.2	18.6
DO	mg/l	4.5 - 8	0	6.8	0	4.4	0	8.5	**DO**		
PH	-	6 - 9	8.3	7.15	6.7	6.5	8.5	6.5	**PH**		
TEMP	0c	40	43	28	37	28	39	32	**TEMP**		
R CL	mg/l	-	0	3	0	2.95	0	3.5	**R CL**		

R CL- Residual chlorine. TEMP- Temperature.

A1,A2,A3-Physico-chemical ETPs. B1,B2,B3-Biological ETPs. C1,C2,C3-Combined chemical-biological ETPs.D1,D2,D3-Chlorination ETPs. Courtesy: Beximco Textile Ltd, Padma Pollycotton Ltd, DBL Textile Ltd, Interstoff Apparel Ltd, Texurop (BD) Ltd. and rests are confidential. From the above performance analysis table 4 , we can figure out the actual

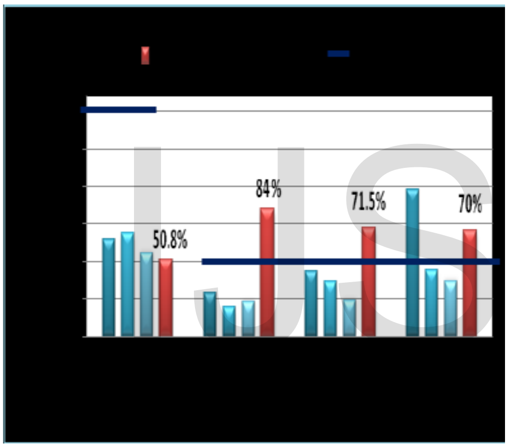
ISSN 2229-5518

scenario of different active ETPs. It is very clear that there are wide variations in average removal efficiency compared to typical efficiency of ETPs. Now take a look at individual efficiency discrimination of important parameters based on performance analysis table 4.

1.4. Chemical oxygen demand (COD):

- Figure **9** shows that except chlorination based ETP D1, other COD levels at discharging points are under maximum permissible limit (MPL).
- In combined bio-chemical method the average COD removal efficiency gained the highest value(70.8%) , in biological method 59.1%.

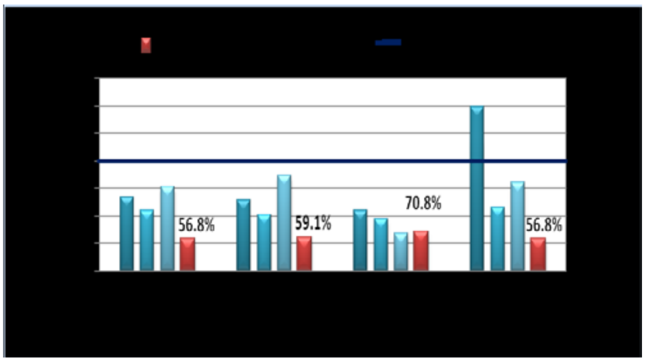
1. Biological oxygen demand (BOD5):



*BOD5 limit (150 mg/l) implies only with physico-chemical method.

- From figure **8** we can see that except chlorination based ETP D1, other BOD5 levels at discharging points are under maximum permissible limit (MPL).
- In biological method the average BOD removal efficiency gained the highest value(84%) compared to other methods.

2. Chemical oxygen demand (COD):



- Figure **9** shows that except chlorination based ETP D1, other COD levels at discharging points are under maximum permissible limit (MPL).
- In combined bio-chemical method the average COD removal efficiency gained the highest value(70.8%) , in biological method 59.1%.

3. Total suspended solids (TSS)

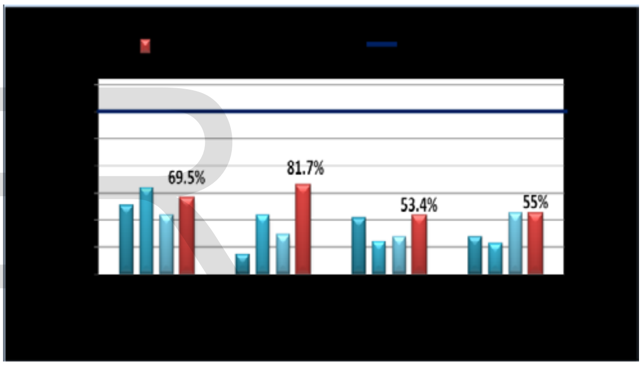


Figure **10** shows TSS levels at discharging points are under maximum permissible limit in each method.

- Among all methods highest average TSS removal efficiency (81.7%) found in biological method.

4. Total dissolved solids (TDS) :

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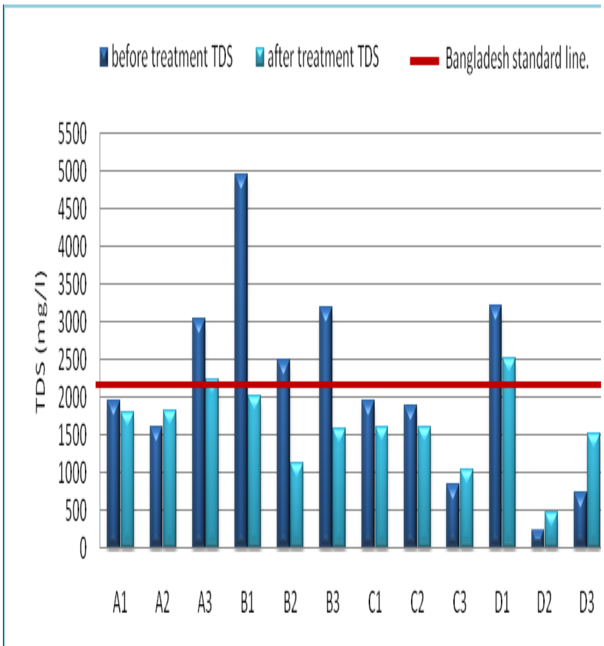
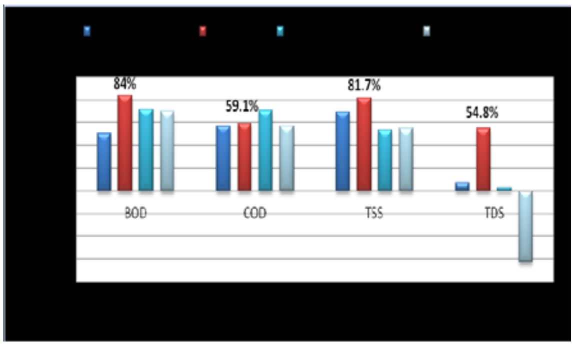


Fig 11: Inlet(BT) & outlet(AT) TDS levels.

- From figure **11** it is found that before treatment TDS level was under discharging standard (2100 mg/l) in ETPs A1,A2,C1,C2,C3,D2,D3.
- Physico-chemical based etp A3 and chlorination based etp D1 can not maintain discharging standard.
- It is also found that except biological method, TDS value increased after treatment in Physico-chemical based etp A2, combined bio-chemical etp C3 and chlorination based etp D2,D3.
- Biological treatment reduces TDS significantly and satisfy discharging standard.

5. Average removal efficiency (RE%) :



- Figure **12** shows that among four methods, highest efficiency in BOD removal (84%) is obtained by biological treatment. - Combined physico-chemical and biological method reduce COD very efficiently. - Highest average efficiency in TSS removal (81.7%) is obtained by biological treatment. - Biological treatment can reduce TDS with high efficiency. Rest of the methods mostly increase TDS after treatment. Great increase in TDS and zero efficiency by oxidation method with chlorine can be realized from figure **12**.

6. Dissolved oxygen (DO) and residual chlorine (RCL):

- From table 4 it is found that, DO level of treated effluent is less than discharge standard (4.5- 8 mg/l) in combined bio-chemical method (C1 & C2) and chlorination method (D2). Chlorine based etp D3 presents higher DO (8.5 mg/l) than permissible limit. Lower DO could be a threat to aquatic life. Organisms undergo stress at reduced DO concentrations that make them less competitive to sustain their species within the aquatic environment.
- In chlorination method residual chlorine is found much higher than permissible limit (0.3 mg/l) which can react with natural organic compounds and produce dangerous disinfection byproducts (DBPs).

Actual scenario in brief:

By physico-chemical process BOD and COD removal efficiency was found 50% and 70% respectively(Nicolaou and Hadjivassilis,1992), BOD and COD removal efficiency was found 90% and 75% respectively by biological treatment [9], In combined biological and physico-chemical method BOD,COD removal efficiency exceeded 90% [7]. Treatment with chlorine gained 55-85% BOD, 55-70% COD reduction efficiency [8]. But analyzing average efficiency of different active ETPs from table 4, it is realized that the actual view is quite different. Physico-chemical as well as highly efficient combined physico-chemical and biological methods can not satisfy discharging standard. Due to high chemical consumption, labor cost, huge quantity toxic sludge disposal problems owners do not run the plant regularly and efficiently. Sometimes it's just for eye wash. It is also found that, treatment capacity of certain ETPs is lower than incoming effluent stream. So, huge quantity wastewater is discharged without any treatment. But owners are bound to run biological plant 24 hours and 365 days to ensure that the bacteria are provided with sufficient "food" (i.e. wastewater) and oxygen to keep them alive. Brief breaks (for a few hours) in operation will probably do little harm but prolonged shut down will deprive the microorganisms of their food and oxygen and will damage the process [3]. That's why in actual practice biological plant is running so efficiently maintaining national standard.

1.5. Ecological perspective:

Biological treatment with activated sludge process (ASP) using aerobic bacteria is very eco-friendly. No hazardous chemicals are required, so probability of water contamination is nearly zero. No bad smell is produced. Possibility of reusing treated water for irrigation and fish life which is impossible in other methods. Very low non-toxic sludge is produced containing negligible amount of toxic heavy metals like lead, chromium, mercury etc. Sludge can be utilized as compost fertilizer.

Table 8: Sludge characteristics.

Parameters	Physico-chemical	Biological	Combined bio-chemical	Chlorination
Sludge quantity	2–5 kg/m3	300 – 400 gm/m3	2–5 kg/m3	Negligible
Sludge toxicity	Highly toxic	Non-toxic	Toxic	-
Sludge disposal problem	Severe	Slight	Medium	-
Sludge disposal cost	High	Very low	High	-
Sludge utilization	Brick	Fertilizer, brick	Brick	-

Courtesy: TEXMAC (BANGLADESH) LIMITED.

Problems with Chlorination:

Breathing small amount of chlorine gas can be deadly. It is toxic to mucous membrane, damage respirational systems, coughing, chest pains, fluid accumulation in lungs. Moreover, chlorination of effluents such as those from dye houses may produce cancer causing chemicals due to the reaction of chlorine with aromatic chemicals in the effluent. These chlorinated organic chemicals are part of a group of chemicals known as **AOX** (aromatic organic halides), and are undesirable. It is therefore recommended **not** to use chlorine in an ETP that treats textile dyeing wastewater.

1.6. Scopes of optimizing effluent generation & toxicity:

Both toxicity and volume of textile effluent is directly related to the cost of operation of the effluent treatment plant. Following attempts can be practiced to minimize effluent generation and toxicity:

- Bleach and Salt bath recovery.
- Dye substitution-Use low-salt reactive dye and metal free dyes with high fixation rate.
- Low liquor ratio dyeing machines. Ex: Thence jet flow dyeing (HK). m:l-1:5
- Cold pad batch dyeing.
- Recycling/reuse of cooling/condensate water.
- Pulsating rinse technology.
- Use biodegradable surfactants such as linear alcohol ethoxylate.
- Caustic scouring is responsible for 54% of total BOD, 49% of total COD, 10-20% of total pollution load. So replace caustic scouring with bio-scouring.
- Replace the use of chlorites and hypochlorites with hydrogen peroxide.
- Right-first-time dyeing.
- Replace chlorinated solvents with unchlorinated alternatives.
- Organic salt so called CLR is useful to consume half amount of Gluber salt or sodium chloride.
- Use enzyme based H2O2 killer instead of salt base H2O2 killer.
- Utilize flow segregation system to reduce pressure on biological treatment unit.

1.7. Constraints of Biological ETP :

- Non biodegradable dye stuffs render the biological treatment ineffective or less efficient.
- Presence of excessive toxic heavy metals prevents microbiological growth, hence efficiency fall down.
- Biological treatment is less effective in high osmotic pressure due to high TDS content in waste water.
- Higher space required.
- Initial investment is higher than other system due to constructing bigger civil works and electromechanical equipments.
- High retention time (12 to 72 hours depends on COD level, COD ≤1000 mg/l need 12 to 24 hours, COD 1500-2000 mg/l required 72 hours typically).
- Low decolorization efficiency of soluble dye stuffs.

III. SUGGESTIONS:

- DO concentration needed for aerobic system 1.5 to 4 mg/l. Generally 2 mg/l is maintained. Higher DO will not increase biodegradation efficiency hence represent energy wastage. Noted that, aeration possesses 25% of total running cost.
- MLSS concentration should be maintained within the range of 1500-3000 mg/l for activated sludge method. - PH should be maintained

ISSN 2229-5518

between 6.5-8.5 and temperature less than 400C in biological reactor.

- Sludge settling characteristics should be checked by SVI (sludge volume index) test. Poor settling sludge will result in low concentration of solids in the return activated sludge thus the concentration of microorganisms drops and subsequently F/M (food per microorganism) ratio increases in the aeration tank which results in a reduced BOD, COD removal efficiency. For excellent sludge settling SVI value should be less than 50.
- Add adsorbents like bentonite clay or activated carbon to biological system in order to eliminate non-biodegradable or microorganism–toxic organic substances (Pala and Tokat, 2002).
- Higher microbial efficiency can be obtained by adding nutrient salts like Urea, Diammonium phosphates (DAP). Nutrients (food) should be provided while plant shutdown.

IV. CONCLUSIONS:

This study revealed that textile effluent treatment with biological methods is highly efficient and cost-effective as well as eco-friendly. There are some constraints specially, extremely high initial investment and space requirements which are major obstacles for small and medium scale factories. Government can take efforts to initialize bank loan to establish effluent treatment plants with minimum interest. Further development is essential to treat inorganic compounds by biological process.

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