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Design evaluation of an effluent treatment plant

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ABSTRACT: Hundreds of Textile industries in Bangladesh produce wastewater as a bi-product of their production mainly due to dyeing and washing of garments. The effluent contains several organic pollutants and color producing substances, which cause severe environmental hazards on both aquatic life and human health. These pollutants can be reduced down to the permissible limit with the help of an Effluent Treatment Plant (ETP). Most of the industries having ETP are not operating their plant regularly due to excessive operational and maintenance cost as they are not designed properly. Thus the design evaluation and development of optimum design of a treatment plant has been adapted as the major objective of the study. The main wastewater quality parameters concerned in this study are Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and color. Simple biological treatment process without prior to chemical treatment has been found suitable to reduce the COD and BOD at a level which comply with the Bangladesh Environmental Conservation Rule (ECR), 1997, provided that optimum operational conditions(aeration period, air flow rate, volumetric loading, F/M ratio etc.) are maintained. In this research the optimum design criteria have been developed and the ability of the chemical treatment process to reduce the pollutants has also been checked. A treatment option has also been recommended for the treatment of the liquid waste generated from textile industry; which is found to be most efficient and economic way to reduce COD, BOD and color. Finally on the basis of the study result, necessary modification of different treatment units of an existing ETP has been proposed in order to increase its treatment capacity.

1 INTRODUCTION

Concept of zero polluting industry is not relevant for Bangladesh. In Bangladesh the Ready Made Garments (RMG) sector employs close to 3.5 million workers, a further 10 million people depend on their livelihood because of the RMG industry. But in running this sector environmental concern is not a great concern and the implementation as well as awareness about the environmental law is very poor. Moreover the industry operators and owners are reluctant to maintain an effluent treatment plant for cost concern. As the options for treating textile wastewater are very expensive, industry owners of a Least Developing Country (LDC) like Bangladesh are often reluctant to allocate their budget for effluent treatment. The industries are always busy to bypass the law and discharging these wastes into surface water course without proper treatment.

In Bangladesh, many textile industries have set up ETPs. These ETPs have been designed by international design firms without considering the local facts. These are simply designed on the basis of some generalized data and involve use of technologies and chemicals which are cost prohibitive. But choosing appropriate and cost effective treatment option is one of the major steps toward reducing pollution from textile industries. In this study wide investigation of proper treatment method and design evaluation of an existing ETP has been made in order to suggest optimum and cost effective way of wastewater treatment.

2. METHODOLOGY

2.1 *Sample collection*

The quality of textile wastewater varies greatly in composition depending on the type of the cloth is to be processed, the type of dye used and the variation in the process regarding yarn treatment. Considering these real facts, preparation of a synthetic sample for study of the efficiency of removal was not rational. So not going for synthetic wastewater, the wastewater was collected from an industry that is already in production and facing problem in treating the wastewater generated.

With the stated purpose, wastewater sample was collected from the textile mill of Standard Group Limited, an export oriented company and its factory at Konabari, Gazipur comprises of sweater manufacturing and washing unit and the composite wastewater that is generated, is treated in an Effluent treatment Plant (ETP). The current wastewater generation rate of the industry is $86m^3$/day. 10 batches of raw wastewater along with 3 batches of treated wastewater sample were collected over a period of December, 2009 to July 2010.

2.2 *Determination of water quality parameters*

Particularly for this study mainly Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) was considered. But color consideration was also incorporated also. For these three (COD, BOD and Color) parameters the appropriate method of treatment and the optimum condition has been studied to achieve maximum possible reduction.

The Winkler test was used to determine the concentration of dissolved oxygen in wastewater samples. Then BOD of a sample was obtained from the determination of dissolved oxygen (DO).From two bottles of completely filled wastewater sample, DO of one sample was measured immediately. Another bottle was kept in dark at 20°C for five days before determining dissolved oxygen. BOD_5 was the difference between DO of these two bottles.

COD of the sample was measured by 'Closed Reflux-Colorimetric method' (SM 5220 D) using COD digestion vial (digested for 2 hours and cooled down), COD digester /reactor & DR-2010 Spectrophotometer.

The concentration of suspended solids in the aeration tank, commonly referred to as the Mixed Liquor Suspended Solids concentration (MLSS), is a crude measure of the biomass within the aeration tank. It was measured in the same way as suspended solids in wastewater by altering a known volume of the mixed liquor sample through filter paper and weighing it after drying in an oven at 105°C. The MLSS is a basic parameter used in the calculation of a number of other operating parameters in mg/l. Some of the MLSS may be inorganic, and under certain circumstances, this may represent a significant proportion of the solids present. To remedy this, many operators estimate the organic fraction of the sludge by measuring the combustible matter present in the MLSS by burning the dried sludge in a muffle furnace at 500°C. If a Gooch crucible is used, after filtering operation remove crucible and filter combination. Dry in an oven at 103 to 105°C for 1hour. If volatile solids are to be measured, ignite at 550°C for 15 min in a muffle furnace. Cool in desiccators to balance to balance temperature and weigh. Repeat cycle of drying or igniting, cooling, desiccating and weighing until a constant weight was obtained or until weight change was less than 4% of the previous weighing or 0.5 mg, whichever was less. This is also expressed in mg/l and is termed the Mixed Liquor Volatile Suspended Solids (MLVSS). But in biological treatment process it is generally assumed that all the solids remain in the mixed liquor is organic and the portion of inorganic solids is negligible; so the MLSS is used almost always interchangeably for MLVSS.

2.3 *Treatment Approaches*

As first approach to the treatment of the wastewater of the Textile mill, laboratory arrangement was made for aeration of the wastewater. The raw wastewater was aerated for different time period to obtain the required detention time by which the effluent of the industry can be treated up to the standard set by DoE.

In case of color removal the efficiency of the biological treatment is not so high. On the other hand presence of toxic metal inhibits the growth of the bacteria in the aeration basin, which can be removed effectively by chemical treatment. The chemical treatment approach includes the selection of type of coagulant, optimum coagulant dose and the need of using any coagulant aid.

As third approach biological treatment prior to chemical treatment was performed to investigate the maximum color removal possible.

As fourth treatment option Chemical Treatment Process Prior to Biological Treatment Process was considered to reduce COD, BOD and color of the effluent. The effects of toxic metal (if any) for this particular wastewater and effects of pre-treatment of the effluent by chemical process on biological treatment is observed by this setup.

3. RESULTS & DISCUSSION

3.1 *Different Points Observed During Field Investigation*

For performing this study appropriate field condition was investigated to relate with laboratory model studies. Various observations were found during the field investigation:

i. 3-4 hr is required to complete a cycle of washing if all the machines are operated simultaneously
ii. No recirculation of sludge into the Aeration Tank to maintain a balanced F/M ratio
iii. Extended aeration occurring as F/M ratio is not maintained
iv. Bio-flocs are disintegrating due to turbulence during entrance to Settling Tank
v. Existing condition of different treatment units are as below:
vi.

Table 1. Capacity and Size of Different Treatment Process Units of the Existing ETP

Operational Units	No. of Unit	Capacity & Size of Each Unit	Detention Time (hr)
Equalization Tank	1	379 m^3	4.40
Aeration Tank	2	658m^3	15.3
Clarifier	2	168m^3	3.90
Sludge Holding Tank	1	74.2m^3	>3 weeks
Sludge Drying Bed	4	35m^2	2 SDB merged with CSSP
Color Sludge storage Pit	1	152m^2	---

3.2 *Analysis of raw wastewater*

The raw wastewater was tested in the laboratory for different parameters. The Chemical Oxygen Demand and Biochemical Oxygen Demand analysis results have been presented below.

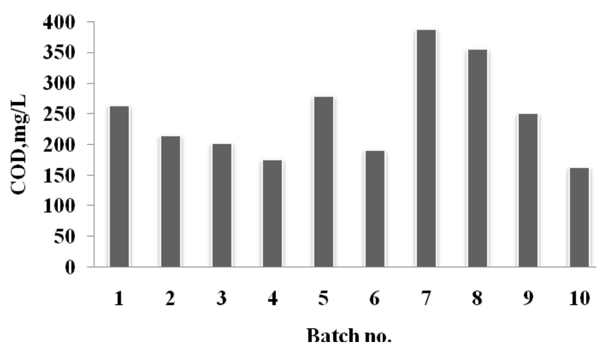

Fig. 1. Variation of raw COD

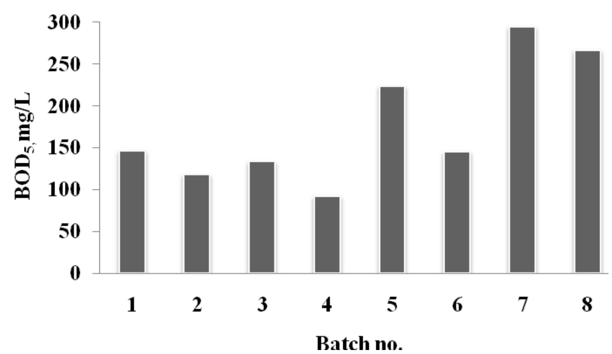

Fig 2. Variation of raw BOD_5

Table 2. Variation of raw wastewater

Type of Impurities	Wastewater Quality Parameters	Concentration Range		Average Concentration	ECR, 1997
		Maximum	Minimum		
Physical	SS in mg/l	263.8	51.7	112	150
	Color in Pt-Co Unit	171	61	117	-
	Grease and Oil	Not found	Not found	Not found	10
Chemical	Electric Conductivity in µS/cm	1562	863	1299	1200
	pH value	8.93	7.14	7.8	6-9
Bio-Chemical	COD in mg/L	388	163	268.57	200
	BOD_5 in mg/L	295	92	177.5	50

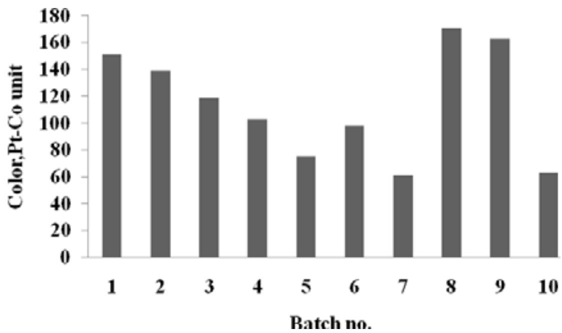

Fig. 3. Batchwise Variation of Raw Color

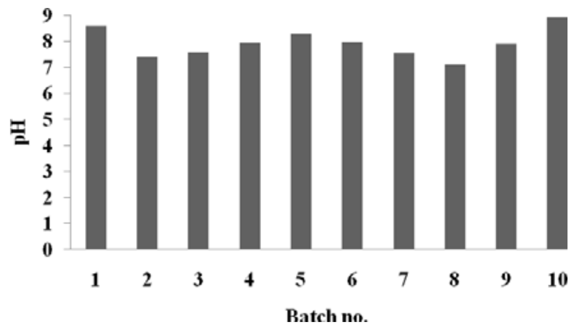

Fig. 4. Batchwise Variation of Raw pH

3.3 *Major concerns*

To bring down COD and BOD value within 200 and 50 mg/L respectly which are the maximum permissible limit set by ECR 1997. For effective COD removal F/M ratio should be maintained within the range of 0.1-0.3.For ensuring safe aquatic life pH should be maintained within the range of 6-9.Color value should be reduced as much as possible since there is no standard value for color.

3.4 *Variation of different water quality parameters with aeration period*

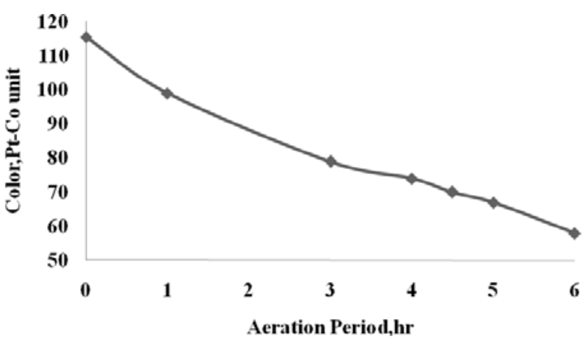

Fig. 5. Effect of Air Floatation Test on Color

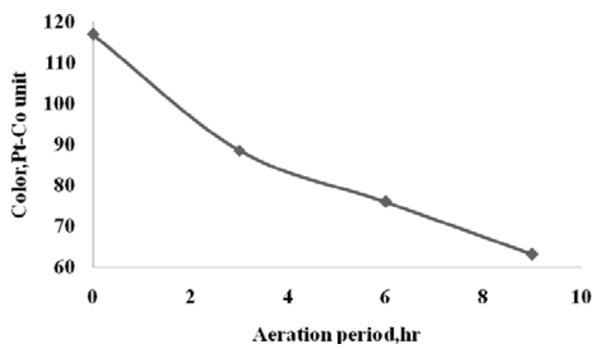

Fig. 6. Variation of Average Color with Aeration Period

3.5 *Findings from laboratory scale model studies*

a) The pH value of the raw sample and treated sample varied from 6 to 9 which is required for safe aquatic life. So there is no requirement for initial pH adjustment.
b) An aeration period of 3 hr is sufficient to reduce the concentration of COD and BOD within the permissible limit. However an aeration period of 6 hr has been adopted considering the volumetric loading (Fig 7).
c) Biological treatment process prior to chemical treatment process showed better COD and BOD removal performance.
d) The rate of COD removal decreases with the increase of Food to Microorganism Ratio. So, an optimum range of F/M ratio (0.1-0.3) has been selected considering the COD removal (Fig 8).
e) Recirculation of sludge is required to maintain the desired F/M ratio.
f) A reasonable portion of color producing substances was separated through simple air floatation process. Though there is not any limiting value for color but the effluent color value seems to be very low (Fig 5).

g) Color particles were further removed due to bio-absorption. Though there is not any limiting value for color but the effluent color value seems to be very low (Fig 6).

h) Biological treatment ahead of chemical treatment showed the maximum COD and BOD removal efficiency (Fig 7 and Fig 8).

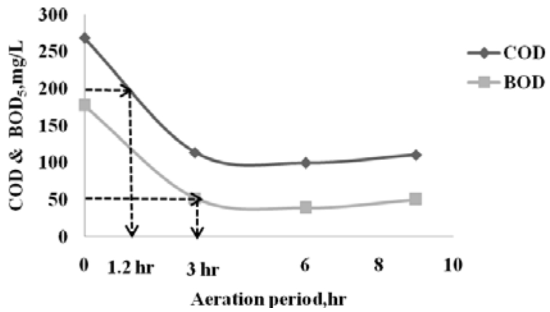

Fig. 7. Variation of Average COD and BOD_5 with Aeration Period

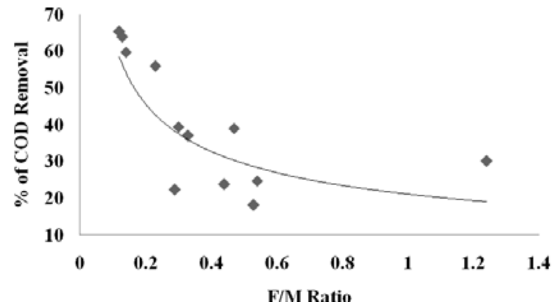

Fig. 8. Effect of Final F/M Ratio on COD Removal

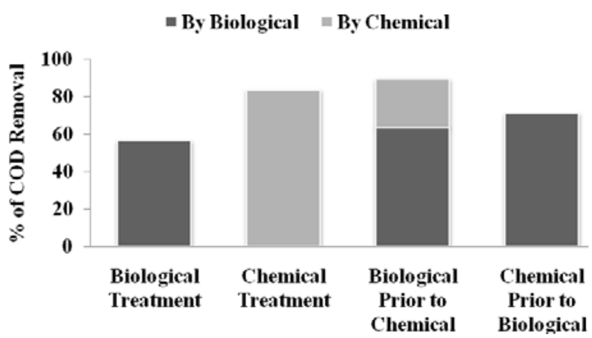

Fig. 9. Comparison of COD Removal by Different Processes

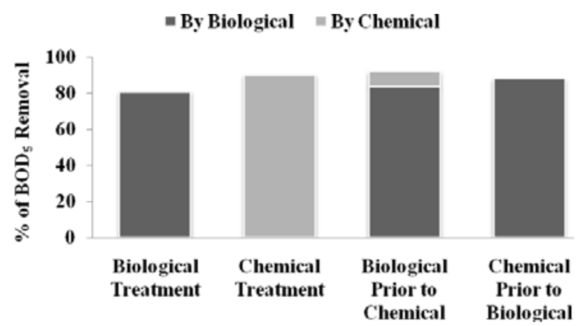

Fig 10.Comparison of BOD Removal by Different Processes

3.6 *Selection of Treatment approach*

Though Biological Treatment Prior to Chemical Treatment process showed maximum removal Efficiency, only Biological Treatment Process have been chosen since Biological Treatment Process is capable of bringing COD and BOD within their permissible limit, low effluent color value and use of chemicals involves cost. So the most cost effective option is Biological Treatment Process.

3.7 *Comparison between Field Performance and Laboratory Model Studies*

Table 3. Field Performance of the Existing ETP

Concentration Present		pH value	EC (µs/cm)	COD (mg/l)	BOD (mg/l)	Color (Pt-Co unit)
ETP Effluent Quality (Treated)	26.11.08*	7.64	969	9	2	42
	03.01.09*	7.94	936	10	3	27
	19.01.10	7.85	967	8	2	20
	25.04.10	7.96	1074	14	4	25
	11.07.10	7.91	1403	20	7	30
	18.07.10	6.93	1471	18	6	48
ETP Effluent Quality (Average Treated)		7.71	1136.67	13.17	4.0	32
Bangladesh ECR,1997		6-9	1200	200	50	-

Note: * From "The Report on the Performance Study of the Existing ETP at Konabari, Gazipur (January, 2009)"

3.8 *Development of Operational & Design Criteria*

i. No need for pH adjustment
ii. Detention time of equalization tank should be 6 hr
iii. Minimum aeration period required 3 hrs
iv. Considering COD removal, minimum volumetric load and volume of aeration tank, aeration time has been taken as 6hr
v. Oxygen requirement is 0.67m³ of Air/hr/m³ of aeration tank
vi. F/M (Food vs. Microorganism) ratio should be maintained between *0.1-0.3*
vii. The rate of sludge production is *3.509* m³ /day
viii. Settled sludge should be recirculated in the aeration tank at the rate of 0.129m³/day to maintain the F/M ratio
ix. Color value is not significant and color producing substances can be separated by simple air floatation process and bio-absorption
x. Chemical Coagulation has been ignored because of its expenses & sufficiency of biological treatment

3.9 *Summary of the Proposed ETP*

*Table 4. Summary of the Proposed ETP**

ETP unit processes	Design Criteria	
	Parameters	Optimum Considerations for Existing ETP
Equalization Tank (ET)	Detention Time	6 hrs
Aeration Tank (AT)	Detention Time	6 hrs
	Volumetric Loading	Maximum 0.7 kg BOD /m^3/day
Settling Tank (ST)	Detention Time	2 hrs
	SOR	28m^3 / m^2 - day
Sludge Digester (SD)	Sludge Production rate	0.17%
	Detention Time	Minimum 15days
	Total Sludge Production	52.632 m^3 / 15days
Sludge Drying Bed	Detention Time	7 days
	Digested Sludge volume	25.35 m^3 / week

* Note- For a discharge of 86m^3/hr having Influent BOD of about 175.5 mg/l

3.10 *Comparison between Optimum Design Condition & Field Condition*

Table 5. Comparison between Existing ETP and Proposed Design

Unit Processes/ Operations	Existing ETP	Optimum Considerations for Existing ETP	Comments on existing ETP
Equalization Tank	Volume = 379 m^3 Detention = 4.4 hrs	Volume = 520 m^3 Detention = 6 hrs	Inadequate
Aeration Tank	Volume = 1316 m^3 Detention = 15.3 hrs	Volume = 520 m^3 Detention = 6 hrs	Over designed
Settling Tank	Volume = 336 m^3 Detention = 3.9 hrs	Volume = 270m^3 Detention = 2 hrs	Over designed
Sludge Digester	Volume = 74.2m^3 Detention > 3 weeks	Volume = 54 m^3 =15 days	Over designed
Sludge Drying Bed	140 m^2	48 m^2	Over designed
Chemical Coagulation	Addition of HCl, Alum & Polymer	No Chemicals	Not Required

3.11 *Major Modifications*

a) *Option 1*(For Q= 86 m^3 /hr):
   Construction of an additional Equalization tank of 140 m^3
b) *Option 2*(For Q= 210 m^3 /hr):
   i. Construction of an additional Equalization tank of 950 m^3
   ii. Construction of an additional Sludge Digester of 50 m^3

3.12 *Minor modifications*

Minor modifications needed for both the options are

i. Modification of inlet arrangement to clarifier so that no turbulence of water occurs
ii. Arrangement of sludge recirculation system to maintain the desired F/M ratio
iii. Modification of Sludge Drying Bed for their alternate use
iv. Modification of Color Sludge Drying Bed
v. Construction of an corrugated sheet shed over the Sludge Drying Bed
vi. Re-use of effluent water through aquaculture

4. CONCLUSION

Considering the environmental issues, the textile mills of Bangladesh should set up and properly use Effluent Treatment Plants. For cost effective operation of ETPs Biological Treatment Process can be introduced. In this manner, textile mills can follow the example discussed here.

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