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Short Communication

TREATMENT OF TEXTILE WASTEWATER WITH CHLORINE: AN EFFECTIVE METHOD

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Abstract: As the chlorination of textile wastewater achieves all the objectives of its treatment such as color removal and reduction of TDS, BOD and COD; and the treated effluents meet the standards set as per Schedule 12-B of the Environment Conservation Rules-1997 (ECR-97, Bangladesh), the treatment of textile wastewater with chlorine gas is a practical technological option for Bangladesh. If this process which is simple if adopted by the textile sector, the ETP operation would be widely practised for its low operating costs because of low price of chlorine produced by local chlor-alkali plants in the country. Satisfactory operation of the ETPs treating textile wastewater with chlorine at low costs has made this process affordable and attractive to the textile sector. Some of the perceived limitations of chlorination outweighs the greater benefits of textile wastewater treatment with chlorine gas leading to cleaner water bodies which receive these effluents otherwise.

Keywords: *Textile wastewater, chlorination, ETP, wastewater treatment*

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1. Introduction

The textile processing industries produce wastewater containing suspended solids, large amount of dissolved solids, unreacted dyestuffs and other chemicals that are used in different stages of dyeing, fixing, washing and other processing. The color fixation efficiency being sometimes less than 60% [1, 2], a significant amount of dyes are lost in the wastewaters. The treatment of textile wastewater is complicated because of significant BOD (Biological Oxygen Demand), COD (Chemical Oxygen Demand) and TDS (Total Dissolved Solids) content plus non-biodegradable nature of organic dyestuffs [3].

The textile wastewater treatment technologies aim at achieving: color removal and reduction of TDS, BOD and COD. Treatment processes include physical, chemical and biological; and they have merits and limitations. In order to meet the environmental requirements, researchers have been making efforts to use a combination of two or more methods for producing an acceptable effluent from the treatment facility. Combination of chlorination and chemical coagulation is reported to meet the environmental requirements for textile wastewater treatment [4].

Historically chlorine was effectively employed for treating industrial wastewater for almost one hundred years ago [5, 6]. Because of high cost of chlorine, the industry then looked for alternative chemicals and treatment system which has led to chemico-physico treatment process requiring more equipment and increased investment. Where chlorine is cheap or available as an otherwise unusable product, its use in the treatment of wastewater can be a desirable option.

Sources of chlorine can be either chlorine gas in cylinder or indirect on-site electrochemical chlorine. The aqueous chlorine as a chemical oxidant produces one atom of oxidizing power per mole of chlorine as shown below.

$$Cl_2 + H_2O \rightarrow 2\,HCl + [O]$$

Thus 71 kg of Chlorine will deliver 16 kg of Oxygen for the desired oxidation process. In spite of the complexities of chlorine oxidation process, chlorine offers the advantage for its ability to destroy organics, colors, odors, cyanide, phenols, detergents etc. Moreover, chlorination renders treated water disinfected [7, 8].

The chemistry of the chlorination of all waters whether potable, wastewaters or industrial wastes is fundamentally the same. The reactions differ because of the variations in species and amounts of interfering substances, both organic and inorganic. The interfering substances are those that either lead to excessive consumption of chlorine or affect the bactericidal efficiency of the residual chlorine [9].

The Department of Environment(DOE), Bangladesh as per ECR-1997 set the following standards for the effluents to be discharged from composite textile plant and large processing unit, Table 1 [10]. DOE has not yet established methods/procedures for measuring these parameters.

It is obvious that if the limit for BOD is 150 ppm, the effluent is unlikely to have significant DO (Dissolved Oxygen) at the point of discharge. For aesthetic reason, the treated water shall be colorless, odorless and clear. Since the determination of COD is less time consuming, COD values can be used as indicator for BOD; and usually the BOD of a wastewater is less than COD.

Drinking water standards of Bangladesh permit residual chlorine in water 0.2 mg/l [11]. Chlorine is very little solu-

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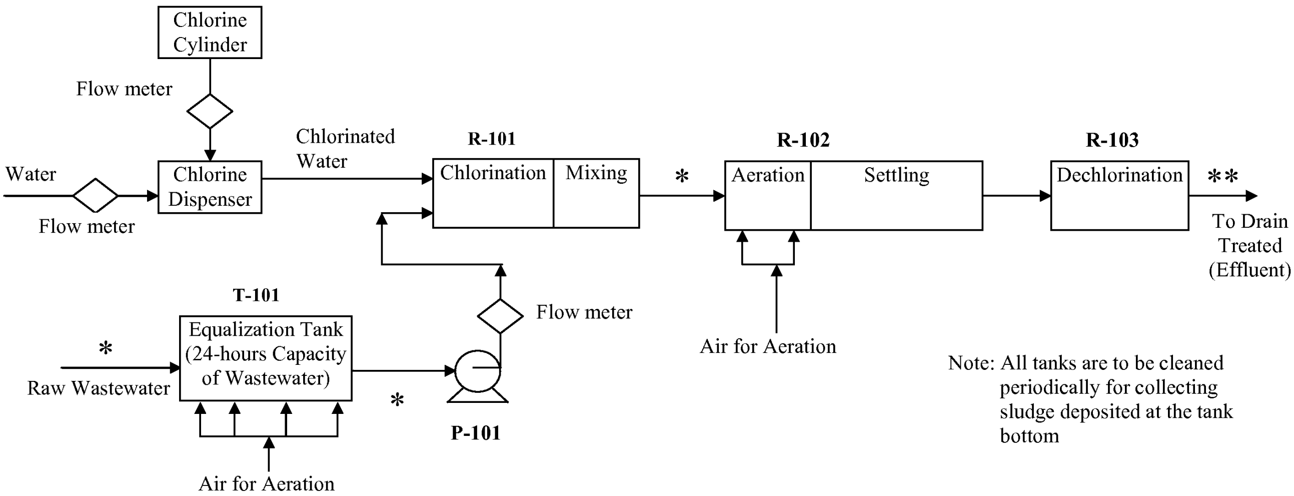

T-101: All raw wastewater is delivered into this tank. Hold up volume is about 3 hours wastewater load. The wastewater is aerated with air from the bottom. Aeration leads to more effective action by chlorine

R-101: Two compartment Tank. Chlorination in the first compartment and the water flows to next compartment through the bottom of the partition

R-102: This is a two compartment tank and it may not be necessarily partitioned physically. Aeration compartment receives the chlorine treated water from R-101 as overflow. The water is aerated with air from the bottom. Thereafter the effluent enters the settling compartment where the suspended materials settle to the bottom of this section. The residence time can be 6-12 hours. Aeration leads to removal of free chlorine and increased contact with oxygen

R-103: Single Compartment Tank for dechlorination by aeration/passing over iron turnings/reacting with sodium bisulphite

P-101: Centrifugal Pump for delivering water to the Chlorination Tank R-101 from the Equalization Tank T-101

* Sampling points for monitoring pH, Color, Chemical Oxygen Demand(COD)/Biological Oxygen Demand(BOD), Dissolved Oxygen(DO), Total Dissolved Solid(TDS), and Total Suspended Solid(TSS); ** Sampling point for monitoring pH and free chlorine

Figure 1: Process flow diagram of the wastewater treatment system based on chlorine gas

Table 1: Standards for textile effluents as per ECR'1997 (schedule 12-B)

Parameters	Standard
pH	6.5-9.0
Suspended Solids (mg/l)	100
BOD_5*, 20°C (mg/l)	150
Oil and Grease (mg/l)	10
Total Dissolved Solids (mg/l)	2100
Wastewater flow (l/kg fabric processed)	100
Total Chromium as Cr (mg/l)	2 **
Sulfide as S(mg/l)	2 **
Phenolic Compounds as C6H5OH (mg/l)	5**

*BOD_5 limit of 150 mg/l implies only with physico-chemical processing
**Special parameters based on type of dye used

ble in water and it reacts reversibly to produce hypochlorous and hydrochloric acids. Up to 0.3 ppm of residual chlorine is acceptable in the treated water at the discharge point. Literature shows the limit for residual chlorine in treated sewage more than 1 ppm [12, 13].

Figure 1 is the Process Flow Diagram (PFD) of the Wastewater Treatment system based on chlorine gas. Existing ETPs (Effluent Treatment Plants) can use the chlorination process with minor modification.

The operation and performance of the wastewater treatment facility require close monitoring of the parameters such as pH, SS (Suspended Solids), TDS, COD, free chlorine, color and temperature at these points of the facility as indicated in the PFD.

- Entry point of wastewater into the Equalization Tank
- Outlet of the Equalization Tank
- Overflow to the Aeration Tank after Chlorination
- Treated water outlet to the drain

Measurement of chlorine in the overflow to the Aeration Tank will help in adjusting chlorination rate. COD being an indicative of BOD, its measurement will help to establish how much organics are being destroyed. On site measurement of these parameters can be easily carried out using portable instruments. For BOD_5 whenever required, samples are to be sent to analytical laboratory.

2. Chloro-organo Compounds and Dioxins

The organics present in the water or wastewater can react with dissolved chlorine forming chloro-organo compounds. The reaction depends on the type of organics (alkanes, alkenes etc), pH and availability of chlorine. Any process that uses chlorine gas directly or chlorine liberating chemicals or where chlorine is produced in the process, formation of chloro-organo compounds is a real possibility if alkanes, alkenes etc are available [6, 14, 15]. Any water or wastewater that contains Fulvic or Humic acids can produce THMs (Trihalomethanes) when these acids react with chlorine if available. The origin of textile wastewater being different from the sewage it is unlikely for these waters to contain Humic and Fulvic acids; so the possibility of THM formation is remote.

This is not a serious limitation in the context of Bangladesh at this stage as the emphasis will be here to encourage the industries to treat the wastewater by operating ETP; and at the same time make efforts to maintain residual chlorine as little as possible.

On the other hand, dioxin has been in the atmosphere before the industrialization and people are concerned with dioxin because it has been found in food chain from various sources. Chlorinated plastics, mainly PVC (polyvinyl chloride) are a major source of chlorine which is necessary for dioxin generation in incinerators. Formation of dioxin needs chlorine, carbon and oxygen simultaneously. 2,3,7,8, TCDD (2, 3,7, 8 tetrachlorodibenzo(p) dioxin) is an example of much talked about non-genotoxic carcinogen. Many of the modern industrial processes generate dioxins but efforts are made to minimize/control their generation. The textile wastewaters that contain very low dissolved oxygen lack a major component, that is, abundance of oxygen to support dioxin formation.

3. Dechlorination of the Treated Effluents

Free chlorine can be removed by using activated carbon bed, by reacting with Sodium Sulfite (Na_2SO_3), Sodium Bisulfite($NaHSO_3$), Sodium Metabisulfite($Na_2S_2O_5$), Sodium Thiosulfate ($Na_2S_2O_3$), Sulfur Dioxide gas(SO_2); by passing over a bed of gypsum, iron turnings or aeration [6, 16].

The ETPs where chlorine based process has been tried, aeration and by flowing the effluents over iron turnings have resulted in removal of chlorine leading to free residual chlorine in the effluent less than 0.2 mg/l. The same performance has been reported where dechlorination has been carried out with Sodium Bisulphite.

4. Disposing ETP's Sludges

Sludges produced by the ETPs are settleable solids consisting of suspended solids that come with raw effluent and those produced through destruction of dissolved solids while treated chemically/biologically including chlorination. These solids continuously settle to the bottom of different units of the ETP such as Equalization Tank, Chlorination Pit, Aeration Unit and Final Settling Basin. Given the sufficient detention time in the plant all the settleable solids shall deposit at the bottom of different units mentioned above. If these units do not have built-in sludge recovery arrangement, the deposited sludges can be removed when the mills remain closed for 48 to 72 hours or during periodic scheduled closure of the mills. All the vessels are to be drained out first and then the sludges are to be removed for final disposal. The raw sludge would contain 95 to 99% by weight water while the partially dried dewatered sludge would contain 25 to 35% by weight solids. The sludge handling system will involve dewatering cum partial drying and incineration of the partially dried sludge as shown in Figure 2.

It is desirable that the individual ETP should have independent "Dewatering Sand Bed" while the partially dried

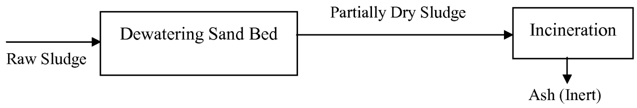

Figure 2: Sludge Handling System

sludge is to be collected from each mill and incinerated in a common incinerator. The ash from the incinerator would be around 10 to 30% of the dried sludge. This ash is inert; and can be disposed at land-fill site safely or used in making bricks.

5. Why this Process?

Though the treatment of textile wastewater could have been a requirement as soon as the industry sector on a new scale had begun in the eighties of the last century but this was not the case as the country then had no environmental regulatory requirement. With the passage of the Environment Act in 1995 and issuance of Environment Conservation Rules in 1997, the Department of Environment, Bangladesh has since then pursuing the textile sector in particular to build and operate wastewater treatment plant.

Chlorination of wastewaters achieves the followings efficiently [4–7, 17, 18]:

1. Elimination of colors and odors
2. Destruction of cyanides and phenols
3. Oxidation of metal ions
4. BOD/COD reduction
5. Control of foams and flies
6. Aiding scum and grease removal
7. Disinfection (destruction and inhibition of the growth of bacteria and algae)

As the chlorination fulfills all the objectives of treating textile wastewater and the treated effluents meet the standards set as per schedule 12-B of ECR'97, the treatment of textile wastewater with chlorine is a practical technological option for Bangladesh. If this process is adopted by this sector, the situation can change dramatically in favor of ETP operation as the process is simple and can be operated at a relatively low cost because of low cost of chlorine in the country. The handling of chlorine gas may appear to be risky; but its wide use in water treatment in hundreds of locations by the process industries and WASA(Water and Sewage Authority of different cities in Bangladesh) assures that chlorine gas can be handled safely by following related procedures.

In view of the investment cost of an ETP using physico-chemical and biological processes plus its operating expenses for chemicals and processing aids in particular, the industry has been responding slowly for building and operating ETPs. The machinery and equipment for ETPs are mostly imported; and the design, construction and commissioning are undertaken often by foreign consultants and firms. Moreover, all the chemicals and processing aids used in ETP operation are imported either from China or India. So, chlorination process provides an opportunity to be self-reliant technologically as well as to reduce import bills for chemicals

Figure 3: Photograph of a Chlorine based system in a textile processing plant

Table 2: Performance data of the testile wastewater treatment plants based on chlorine

Parameters	Plant-A		Plant-B		Plant-C		Plant-D	Plant-E	Plant-F	Plant-G	Plant-H	Standard (ECR-97: Schedule 12-B)
	BT	AT	BT	AT	BT	AT	AT	AT	AT	AT	AT	
PH	10.62	7.46	8.5	6.5	-	-	7.18	7.28	6.95	7.3	7.15	6.5-9.0
TSS, mg/l	-	-	69	56.2	-	-	70	19	14	46	34	100
TDS, mg/l	6800	2010	727	1519	-	-	1228	2024	1673	1490	2518	2100
COD, mg/l	256	128	480	160	562	206	148	475	218	-	299	–
BOD5, mg/l	86	40	230	36	272	50	60	112.5	40	76	98	150
Residual Chlorine, mg/l	-	-	-	-	-	-	0.01	0.04	2.95	3.5	3	–
DO, mg/l	-	-	0	8.5	-	-	-	5.11	4.25	6.2	6.8	–

BT: Before Treatment, AT: After Treatment

etc., plus foreign currency expenses for plant equipment and fees for engineering and other services.

6. Where the Treatment of Textile Wastewater with Chlorine Gas have been Adopted?

Since November 2008, the textile wastewaters have been treated with chlorine gas in the existing ETPs at 30 textile composite industries around Dhaka. The ETPs have been slightly modified to introduce chlorinated water from the chlorine dispenser. The ETPs have been producing effluents that meet the requirements of ECR-97(Schedule 12-B). Operating experiences reveal that the cost of chlorine consumed is very low compared to the chemicals and aids used previously. These industries are now eager and committed to operate ETPs.

Satisfactory operation of ETPs would require monitoring of pH, TDS, color, odor and free chlorine so that the right dose of chlorination is employed. In some ETPs adjustment of pH before chlorination and after treatment may be required. Figure 3 is the photograph of a chlorine based system in operation in a textile processing plant.

7. Performance of ETPs using Chlorine Gas

The performance data of some of the treatment plants using chlorine gas are presented in Table 2, and it is evident from these data that the ETPs using chlorination are performing satisfactorily. The treated effluents from the ETPs meet the set standards of Schedule 12-B of ECR'97.

8. Costs of ETP Operation with Chlorine

A comparison of the costs of operating ETPs with usual chemicals and aids against that with chlorine gas has been made and is presented in Table 3.

It is evident from Table 3 that the savings are significant and make the process based on chlorine financially attractive

The treatment of wastewater with chlorine gas is a proven process and this was discarded primarily for high cost of chlorine gas. The situation is different in Bangladesh and

Table 3: Costs of operation of ETPs with conventional chemicals Vs Chlorine gas in Cylinder

ETPs	Cost of Chemicals/m^3 of effluent, Tk	Cost of Chlorine /m^3 of effluent, Tk
M	7.57	1
N	5.59	1.6
P	4.98	1.7
Q	12.67	1.87
R	13.25	2.81
X	15.92	2.5

Chlorine: Tk. 7.50 /kg, $FeSO_4 \cdot 7\,H_2O$: Tk. 30/kg, Lime Tk. 14/kg, Polymer: Tk. 650/kg, HCl: Tk. 4-5/kg, and Sodium Hypochlorite:Tk.5/litre

the cost of chlorine here favors the adoption of this proven process.

The priority and emphasis today are to make the industry treat the wastewater. The objective is to be compliance by the industry to achieve the standards for effluents. Fines, jails or closure of the industry are not the performance criteria for DOE, rather DOE's performance is to be judged by how many industries operate ETP for treating their wastewater and to what extent the set standards are achieved.

This process provides an opportunity for both the industry and DOE to perform in a Win-Win situation. Instead of being insincere with our mission to serve the nation and its people by ensuring a clean environment, both the parties should strive hard to operate ETPs for complying with ECR-97 requirements. The wastewater treatment with chlorine gas can make all the difference by doing something positive rather than being smart by doing nothing purposefully.

9. Conclusion

The existing pollution level of the water bodies from the textile wastewater will be significantly reduced if this simple technology is adopted. The operation of ETPs using chlorine by the textile sector would be affordable.

The textile wastewater treatment with chlorine provides an opportunity to be self-reliant technologically. It will reduce both import of chemicals etc. and foreign currency expenses for plant equipment and engineering services now needed for the systems using physico-chemical and biological processes.

This alternative use of chlorine will make the chlor-alkali industry sector to grow further to produce all the caustic soda required in the country as well as to achieve full capacity utilization of the existing plants. This means: development of chemical industries, technological self-reliance and cleaner water bodies through cost-effective operation of ETPs.

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