Dyes Removal from Textile Wastewater by Chemical Treatment

Moustafa Abd Elmoniem Ashmawy

Civil Engineering Department, Faculty of Engineering – Mattaria, Helwan University, Egypt
Email: mashmawy95@yahoo.com

Abstract: Removal of dyes from textile wastewater is a big challenge to protect the environment and water bodies. In this research treatment of the wastewater produced from the dyeing and finishing stages in the textile industry by chemical aided processes is investigated. Several parameters such as wastewater conductivity, COD and total dissolved salts (TDS) were considered. Different chemicals were applied to the industrial wastewater and optimum operating doses were experimentally determined. Application of ferric chloride ($FeCl_3$) as coagulant aid, polyacrylamide polymer as flocculation aid, and bentonite clay as pH adjustment was able to reduce contaminants to the permissible level by the Egyptian environmental regulations for the discharge of treated industrial effluents into the municipal wastewater collection system. Although the use of ferric chloride, polyacrylamide polymer and bentonite cause increase in the TDS and conductivity but final effluent was still within the acceptable limit. The applied chemical treatment removal efficiency for BOD, COD and TSS reached up to 74%, 92% and 74 % respectively. The produced sludge was recycled after being pressed by a local manufactured cloth fiber filter where fabrication of bricks from the produced sludge was possible.
[Moustafa Abd Elmoniem Ashmawy. **Dyes Removal from Textile Wastewater by Chemical Treatment.** *Life Sci J* 2016;13(12):85-92]. ISSN: 1097-8135 (Print) / ISSN: 2372-613X (Online). http://www.lifesciencesite.com. 12. doi:10.7537/marslsj131216.12.

Keywords: Industrial Wastewater Treatment, Textile Industry, Chemical Treatment, Dyeing process, Coagulants.

1. Introduction

Water is the most strategically important resource on Earth essential for urban, industrial and agricultural needs especially with the continuous increase in population and economic activities which makes the shortage of water resources more severe. With the need for disposal of both domestic and industrial effluents, industrialization and urbanization have accelerated pollution in the water bodies environment, hence treatment and reuse of industrial treated wastewater is becoming of extreme importance (Xujie Lu et al., 2010).

In Industry, water is used for various applications and its quality changes due to introduction of contaminants. The remediation of industrial wastewaters requires more robust treatment schemes than typical municipal wastewater treatment systems. This is because the characteristics of industrial wastewater treatment plant influents vary from one industry to another depending on the activities and applications (T.P. Knepper et al., 2000).

In textile industry, dyeing and finishing are two important steps in the manufacturing process involving dyeing of man-made or natural fibers to the desired permanent colors and processing of those fibers into final commercial products (Sheng H. Lin and Ming, L. Chen, 1995).

It should be noted that dyeing and finishing process of textile is characterized by high water consumption used for multiple washing and rinsing cycles. In typical dyeing and finishing mill, about 150 m3 of water are consumed on the average for every ton of cloths processed. Reuse of wastewater represents an economic and ecological challenge for textile sector (Xujie Lu et al., 2010).

It is worth mentioning that pollutants present in textile wastewater include heat, alkalinity, organic and inorganic matter, heavy metals, sludge, giving a high content of organic matter (COD) and color problem depending on different forms of dyes, surfactants and textile additives materials used in the process. Textile dyes can be of different kinds, such as; acid, basic, disperse and reactive salts. The presences of salts in textile dyeing wastewater have been identified as a potential problem. Many salts are either used as raw materials or produced as by-products of neutralization or other reactions in textile wet processes. Salt concentrations in effluent from cotton dyeing as an example may reach 2,000 to 3,000 ppm.

However, the major part of the waste generated by the textile chain is represented by the wastewater resulted from the wet processing stages. These stages-streams-contain a wide range of contaminant which must be removed from the effluent before their disposal. Organic and inorganic compounds used in the textile processes are discharged in the wastewater produced from this industry causing a real problem for the surrounding environment and beside the direct environmental impact of this wastewater, the large consumption of water resource is becoming intolerable in countries subject to real or potential water shortage (Joseph Elgi Italia Srl, 2007).

In treatment of textile wastewater by Tak-Hyun Kim, et al., 2002, COD and color removals of 95.4% and 98.5% were achieved by pilot scale treatment included application of fluidized biofilm process combined to chemical coagulation and electrochemical oxidation. The fluidized biofilm showed 68.8% of chemical demand (COD) and 54.5% of color removal efficiency, even though using relatively low MLSS concentration and short sludge retention time.

On the other hand, Ilgi Karapinar Kapdan and Sabiha Alparslan, 2004, indicated that over 85% decolonization and about 90% COD removal efficiency can be obtained by using a sequential anaerobic packed column reactor and an activated sludge unit operated continuously for treatment of a textile industry wastewater, this research took place at Izmir, Turkey. A facultative anaerobic PDW was used as dominant microbial culture in the anaerobic unit for de-colorization. The process consisted of an anaerobic packed column and a conventional activated sludge unit which was fed with effluent from an anaerobic unit. Experimental results indicated that the system could be operated at retention time of 18 hours, under 3000 mg /1 initial COD concentration and 100 mg/1dyestuff concentration and over 85% de-colorization efficiency in the anaerobic reactor can be obtained. No significant color removal (only 15%) was observed under aerobic conditions while COD removal was mainly obtained in the aerobic unit with maximum of 90% efficiency.

Muhammad Saqib Nawaz and Muhammad Ahsan, 2014, concluded that no single biological or physico-chemical treatment technique was found capable of removing more than 80% of the influent COD, TSS and color simultaneously from the textile wastewater, while conventional activated sludge (CAS) treatment followed by effluent polishing with the sand filtration (SF) and activated carbon adsorption columns was proved to be the most promising process achieving COD, TSS and color removal efficiencies of 81.6%, 88.5%and 94.5% respectively.

Nidheesh, P. and Gandhimathi, R. 2014, applied electro-Fenton (EF) process in both batch and continuous modes of operation with graphite plates as both anodes and cathodes. The results showed that 57% of COD and 83% of color from the wastewater were removed at the optimal conditions in batch mode. In continuous mode, only 67.7% of color and 37% COD were removed using a bubble column reactor.

Also, Bhattacharyya, D. and Singh, K. 2010, applied both anaerobic two-phase reactor and a conventional single-phase reactor system in treatment of a synthetic dye wastewater. The two-phase reactor setup used four anaerobic reactors based on up flow anaerobic sludge blanket technology as acid reactors and an expanded granular sludge bed (EGSB) reactor as a methane reactor. The conclusion showed that with hydraulic retention time (HRT) as low as 7.5 hours at least 90% and 75% removal of COD and color, respectively were achieved.

2. Materials and Methods

The experimental work was carried out at the wastewater treatment plant located at MAC carpet factory at 10^{th} of Ramadan City, Egypt. The plant receives a daily flow ranging from 40-60 m3/hr. The wastewater generated during manufacturing processes (dyeing and finishing processes) in addition to the water used for washing coloring pipes is collected and discharged into the wastewater treatment plant.

The manufacturing processes are applied on white carpets to transfer them into final products with various designs, depending on the market demand, Fig.(1) shows a schematic diagram for industrial process units and location of wastewater generation as well as the collection system to the treatment plant. The daily water consumption measured for this process is 1050 m^3 while wastewater discharge was measured to be in the range of 1000 m^3daily.

2.1 Manufacturing Processes

Manufacturing process starts with the production of white carpets at the textile production factory after which carpets are moved to the dyenin and finishing entrance area for preparation to the next stages.

2.1.1 Dyeing and Printing Stage

The colored dyes are applied on the white carpets after adding the thickeners compounds and auxiliaries. Thickeners like polyacrylate and auxiliaries which may be citric acid or sodium hydroxide is added to improve the efficiency of the dying and printing process, about (15%-20%) of the total daily wastewater of the facory is generated at this stage.

2.1.2 Steaming and Washing Stage

The saturated steam is applied to the dyed and printed carpets to stabilize design colors in the streaming area without any water usage, after this the washing stage takes place where the excess dyes and thickeners are washed out from the dyed and printed carpets. About (80%-85%) of the total wastewater discharge of the factory is generated at this stage. After this dyed and printed carpet are set at the drying area where carpets are dried by ovens before storing.

2.1.3 Coloring laboratory

In the coloring laboratory the dyeing powders are dissolved in water to get the dyeing solution and mixed with thickeners compounds like polyacrylate and auxiliaries which may be citric acid - Sodium hydroxide to improve the efficiency of the dying and printing process. Dyes is carried by pressure pipes from coloring kitchen to be used in production line. Each design of carpet needs different dye colors, Before starting a new process (dyeing a new carpet), those pressured pipe need to be washed and cleaned so that the colors are not mixed in the new process and gives non conrolled results. This last step consumes large amount of water that is also disposed off as wastewater discharged as well to the treatment plant.

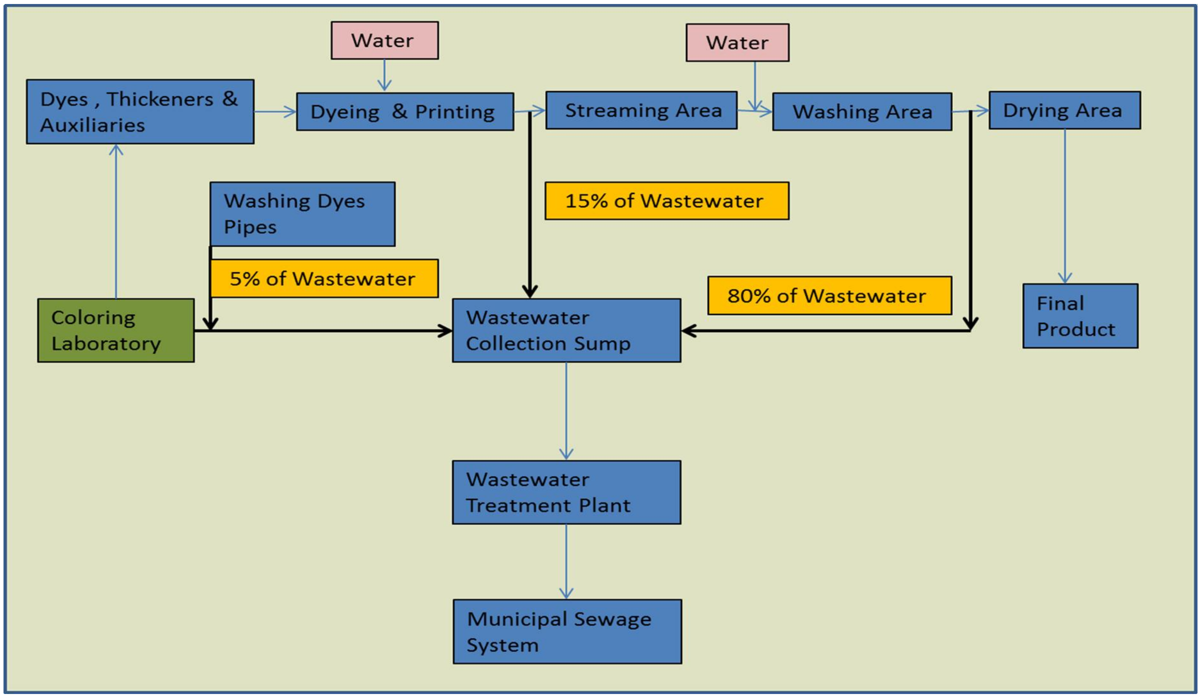

Fig.(1) Schematic Diagram for the Dying and Finishing Process at MAC Factory, Egypt

2.2 Waste Water Treatment Plant Description and Sampling Locations

A physical chemical wastewater plant of average capacity of 40 m^3/hr and max capacity of 60 m^3/hr is used for treatment of the dyeing and finishing processes at this textile factory. The plant included the following units:

2.2.1Equalization Tank

The objective of equalization tank is to minimize and control fluctuation in wastewater characteristics in order to provide optimum conditions for subsequent treatment process and to minimizing flow surges to the physical chemical treatment plant especially with the non-continuous flow that result from the manufacturing process. In addition, adjustment of pH to minimize the chemical requirements necessary for neutralization, chemical dose control and temperature reduction is also among the objectives of this tank.

It should be noted that sedimentation resulted from of the thickeners compounds used in printing process is usually settled at the equalization tank and periodic cleaning of the tank is a must. For the ease of such performance the tank was divided into two compartments one named as collecting pit and the other is called the equalization tank (Fig.2).

2.2.2 Rapid-Static Mixing and Final Sedimentation

Rapid mechanical mixers installed in a 15m^3 tank are used to mix chemicals (coagulant aid, flocculent aid, pH correction and decolorized aid) with process water to prepare the mixture that is then discharged into a rectangular tank of 30 m^3 capacity equipped with baffle walls to increase the water path and to guarantee continuous mixing and uniform distribution of the mixture solution with the influent wastewater. Mixing tanks are followed by a lamella gravity settler tank with 30 m^3 capacity acting as final sedimentation tank where lamella sheets are placed in 45^o degrees slope and 15-20 cm spacing. The effluent from this tank is directed to the final disposal point connected to the city sewage network with facilities of returning the treated effluent to the plant inlet if the treated wastewater samples were not in conformity with the Egyptian requirements for disposal of effluents into municipal network.

2.3-Plant operation and monitoring

The wastewater treatment plant is operating in patch sequence every 20 min according to the interrupted flow received from the industrial processes at a flow rate of 40 m^3/hr after being collected in the equalization tank. Chemicals are added to the rapid mixing tank by three dosing pumps each of capacity up to 50 lit/hr. The ferric chloride ($FeCl_3$) is used as coagulant aid to enhance removing of suspended solids from wastewater by sedimentation. During the study jar- test was carried out to optimize the required dose of the different proposed chemicals for treatment. Ferric chloride solution doses from 25 to 300 mg/l were exercised at different concentrations where optimum dose was found to be 260 mg/l at concentration of 40%.

On the other hand, polyacrylamide polymer was used as a flocculent aid that improves the settling velocity. The polymer powder is first mixed with water to form a solution with the desired concentration before being added to the mixing tank. More over the bentonite clay was used as it has characteristics that decolorized waste water, adsorb sinead and phenol in addition to adjusting the pH. This bentonite clay powder is added to the mixing tank after becoming in suspension form as well. The optimum doses for polyacrylamide polymer and bentonite clay were found to be 200mg/l and 500 mg/l respectively. In addition asdic acid (CH3COOH) and in sometimes sodium hydroxide (NaOH) was added at the exit point to adjust pH if necessary to meet the required values by the implemented regulating law.

Samples were collected on routine bases from the different unites of the plant to assess and evaluate the overall efficiency of the plant, the performance of each unit under the optimum doses of the different treatment aids as well as the assessment of the treated effluent quality for discharge into the municipal sewers and its conformity with the Egyptian regulations in this context (called to be law No.93). Fig.(2) shows the samples location and Fig.(3) shows the preparation of the coagulant aids solutions.

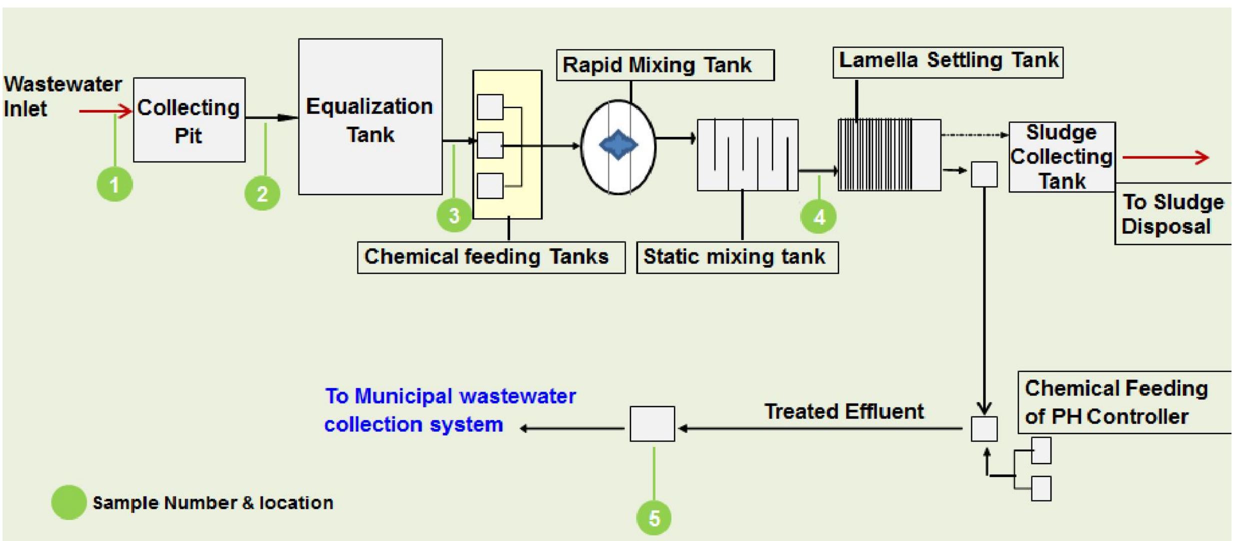

Fig.(2) Wastewater treatment plant components and samples location

Ferric chloride solution Bentonite clay powder polyacrylamide powder

Fig.(3) Preparation of the coagulant aids solutions.

3. Result and Discussion

Results of the routine analyses carried out for the influent wastewater to the treatment plant and the treated effluent are presented in Table (1), where typical characteristics of wastewater produced from Dyeing and finishing process can be seen. Although correlation between TSS and BOD concentration is easily recognized as shown in Fig.(4), the percentage of COD/BOD concentrations in both effluent and effluent wastewater represents typical industrial wastewater configuration. While domestic wastewater has a norm of 1.2 to 1.3 of COD to BOD ratio, this ratio defers from one industry to another according to the industry type and the additives and chemicals used in this industry. However such a ratio is always higher in industrial wastewater than this of the domestic ones. Results of the generated wastewater after the dyeing step showed a percentage of COD to BOD ranged from 6 times to 6.5 times. In general such high values of COD need either anaerobic treatment or special chemical treatment (M.A. Ashmawy et al., 2003)

On the other hand, requirement of the Egyptian environmental law is limited by 800 mg/l of COD before discharging of industrial treated effluent into municipal waste collection sewers.

With the application of ferric chloride and polyacrylamide polymer as coagulant and flocculent aid in optimum doses of 260 mg/l and 200 mg/l and with the application of bentonite clay of 500 mg/l, a significant increase in both TDS and conductivity was recognized. Tables (1) and (2) show an increase in TDS from average value of 327 mg/l in the influent wastewater to an average of 700 mg/l in the treated effluent with almost double the influent values. A typical correlation between the TDS and conductivity is also recognized in both influent wastewater and the treated effluent flow as shown in Fig.(5) where the same increase in conductivity took place.

Table (1) Summary of average results of influent parameters throughout the study period

Week No.	**Parameter**						
	pH	**TSS (mg/l)**	**BOD (mg/l)**	**COD (mg/l)**	**TDS (mg/l)**	**Conductivity**	**Temp.(C^o)**
1	7.13	228	532	3130	307.7	603.3	25.1
2	7.24	265	601	3978	369.5	737.0	24.5
3	7.25	235	574	3652	313.9	626.8	26.4
4	7.18	256	612	3989	361.7	715.5	25.5
5	7.15	232	555	3327	308.4	604.3	26.2
6	7.25	241	540	3582	305.7	589.1	26.8

Table (2) Summary of average results of effluent parameters throughout the study period

Week No.	**Parameter**						
	pH	**TSS (mg/l)**	**BOD (mg/l)**	**COD (mg/l)**	**TDS (mg/l)**	**Conductivity**	**Temp.(C^o)**
1	7.60	60	147	258	754.4	1508.1	23.8
2	7.90	63	150	278	675.3	1270.7	24.5
3	7.94	56	139	265	738.2	1458.8	26.0
4	7.56	62	154	267	629.4	1228.8	25.5
5	7.47	68	160	280	742.1	1468.1	26.1
6	7.73	59	135	251	663.3	1459.8	27.1

On the other hand Table (3) shows the different parameters of wastewater characteristics in the influent and effluent flow from the treatment plant in comparison to the limits of the Egyptian law for discharge of industrial treated wastewater to the municipal sewers. In general the effluent characteristics met the requirement of the Egyptian law and the applied process was convenient for the industry as long as discharge to municipal sewers is considered.

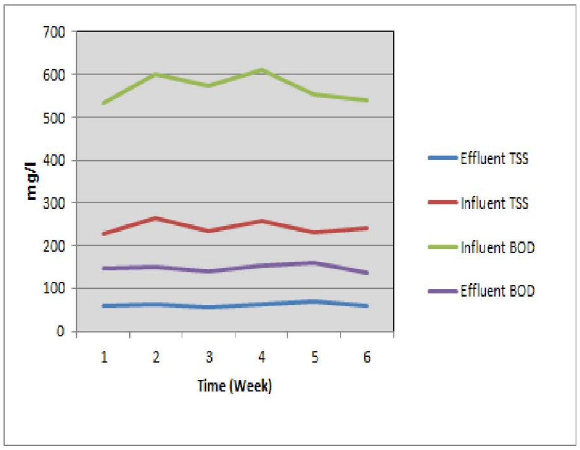

Fig.(4) Influent & Effluent TSS - BOD

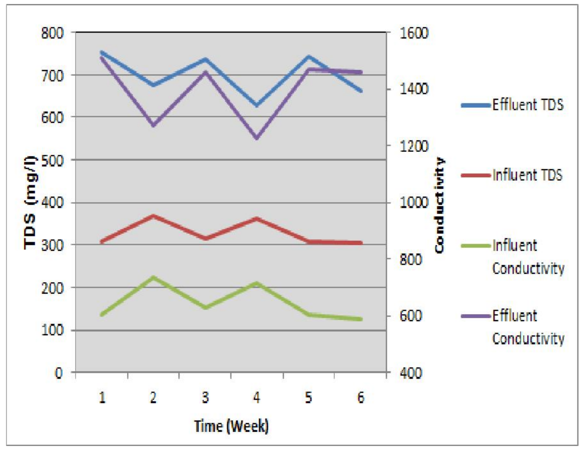

Fig.(5) Influent & Effluent TDS - Conductivity

Table (3) Influent and Effluent characteristics and limits of the Egyptian environmental law

Parameters	Unit	Influent	Effluent	Limits of the Egyptian law
pH	-	7.2	7.3	6-9.5
Settleable Matter (10 min)	ml/l	0.1	N.D.	8
Settleable Matter (30 min)	ml/l	0.1	N.D.	15
Biological Oxygen Demand (BOD)	mg/l	565	147	600
Chemical Oxygen Demand (COD)	mg/l	3136	258	110
Total Suspended Solids (TSS)	mg/l	228	60	800
Oil & Grease	mg/l	76	9.6	100
Sulfide (S^{2-})	mg/l	8.7	7.6	10
Total Kjeldahl Nitrogen	mg/l	40.3	26.9	Not assigned
Phosphate (PO_4^{3-})	mg/l	0.57	0.15	25
Phenol	mg/l	0.15	ND	0.05
Cyanide	mg/l	ND	ND	2
Chromium (Cr)	mg/l	ND	ND	-
Nickel (Ni)	mg/l	ND	ND	0.1
Cadmium (Cd)	mg/l	ND	ND	0.2
Lead (Pb)	mg/l	ND	ND	0.1
Copper (Cu)	mg/l	ND	ND	1.5

It should be noted that although the used coloring and thickening compounds used in the dyeing process are both of high alkalinity nature which should have resulted in high pH values of the influent flow to the wastewater treatment plant, but the huge amount of water used in the dyeing and finishing stages of the carpet factories played a role in keeping the pH values in the normal levels. However it happened occasionally during using the study period with the application of certain compounds in the dyeing process that the plant received higher values of pH reached up to 8.9 and was neutralized through the treatment stages and at the effluent discharging point by the aid of the pH controller.

On the other hand, to evaluate the performance of the individual treatment units as well as the added value from the used chemical compounds in treatment of the wastewater produced after the dyeing and finishing steps, samples were collected after each unit and results of samples analyses are shown in Table (4) as well as Fig.(6), while Fig.(7) shows the influent and treated effluent wastewater samples.

Table (4) Monitoring of the performance of the individual treatment units

Sample No.	Parameter		
	BOD (mg/L)	**COD (mg/L)**	**TSS (mg/L)**
1 (Influent)	565	3136	228
2 (after collecting pit)	412	1834	224
3 (after equalization tank)	320	1535	207
4 (after static mixing tank)	300	768	801
5 (Influent)	147	258	60

Results showed an overall BOD, COD and TSS removal efficiency of 74%, 92% and 74% respectively. This result of a batch physical-chemical processes for treatment of dyeing wastewater is in conformity with the findings of Muhammad Saqib Nawaz and Muhammad Ahsan, 2014.

3.1 Sludge collection and treatment

Two types of sludge are produced from the treatment plant. Thickeners used during the dyeing and coloring process are settled at the first compartment of the equalization tank which is called the collecting pit and evacuated every six months by means of evacuation pumps to a disposal area at a nearby sanitary landfill. In addition sludge produced from the lamella separator tank is pumped to a local manufactured cloth fiber filter for thickening. Thickened sludge are collected from filters manually twice a week and re used in bricks fabrication. The measured sludge volume index for the lamella separator was in the range of 25 ml/g.

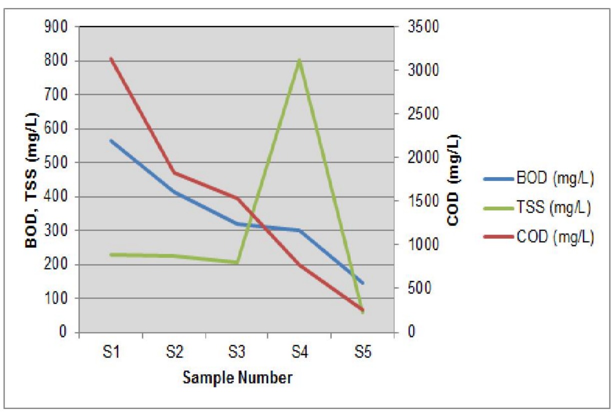

Fig.(6) Treatment stages wastewater parameters

Fig.(7) Influent and Effluent Wastewater

4. Conclusion and Recommendations

- The applied chemical treatment process is applicable for treatment of the wastewater generated from the dyeing and finishing processes at the textile factories specially carpets production factories as long as the final disposal into municipal wastewater collection system is considered as per the Egyptian environmental regulations.
- Although the use of ferric chloride, polyacrylamide polymer and bentonite cause increase in the TDS and conductivity, the overall applied treatment process was able to reduce the level of contaminants at the plant effluent to the acceptable limits.
- Over all BOD, COD and TSS removal efficiency reached up to 74%, 92% and 74% respectively with the application of ferric chloride(fecl3) in concentration of 260 mg/l as coagulant aid, polyacrylamide polymer in concentration of 200 mg/l as flocculation aid, and 500 mg/l of bentonite clay as PH adjustment, decolorized and adsorption aid.
- The produced sludge is of a re-usable quality after being pressed by a local manufactured cloth fiber filters.
- Assessment of applying anaerobic treatment prior to the chemical treatment to reduce the relatively high chemicals cost is recommended for future application.

References:

1. Bhattacharyya, D. and Singh, K. 2010 “Textile Dye Removal in Single-Phase and Two-Phase Anaerobic Biotreatment Systems”, ASCE (10).1061, 250-257, 2010.
2. Joseph Elgi Italia Srl, Wastewater treatment textile industry, Pakistan textile journal October 2007:60-66, 2007.
3. Ilgi Karapinar Kapdan, Meryem Tekol and Fusun Sengul, 2003 “Decolorization of simulated textile wastewater in an anaerobic-aerobic sequential treatment system”, Process Biochemistry 38(7):1031-1037, 2003.
4. M.A. Ashmawy, W. Fuchs and I.H. Alhattab, 2003 “Assessment of Biological Wastewater Treatment with Application of Membranes”, The fourth international conference for low cost waste water treatment, National Centre for Research, Cairo, Egypt, 2003.
5. Muhammad Saqib Nawaz and Muhammad Ahsan, 2014 “Comparison of physico-chemical, advanced oxidation and biological techniques for the textile wastewater treatment, AEJ - Alexandria Engineering Journal 53(3):717-722, 2014.
6. Nidheesh, P. and Gandhimathi, R, 2015 “Textile wastewater treatment by electro-fenton process in batch and continuous modes”, Desalination and water treatment 55(1), 2015.
7. Sheng H. Lin and Ming L. Chen, 1996 “Treatment of textile wastewater by chemical methods for reuse”, Water Research 31(4):868-876, 1996.
8. Tak-Hyun Kim, Chulhwan Park, Jinwon Lee, Eung-Bai Shin and Sangyong Kim, 2002 “Pilot scale treatment of textile wastewater by combined process (fluidized biofilm process–chemical coagulation–electrochemical oxidation)”, Water Research (36): 3979–3988, 2002.
9. T.P. Knepper, J. Muller, T. Wulff, A. Maes, 2000 “Unknown bisethylisooctanollactone isomers in industrial wastewater, isolation, identification and occurrence in surface water”, J. Chromatogr. A 889 (1–2):245–252, 2000.
10. Xujie Lu, Lin Liu, Rongrong Liu, Jihua Chen, 2010 ”Textile wastewater reuse as an alternative water source for dyeing and finishing processes: A case study “, Desalination 258(1):229-232, 2010.

12/25/2016