Egypt.J.Chem. **Vol. 62**, No. 4. pp. 609- 620 (2019)

Egyptian Journal of Chemistry
http://ejchem.journals.ekb.eg/

Cost-effective Physicochemical Treatment of Carpet Industrial Wastewater for Reuse

F. A. Nasr, I. Abdelfattah*, A. M. Shana
Water Pollution Research Department, National Research Centre, 33 EL Bohouth St., P.O. 12622, Dokki, Giza, Egypt.

THE MAIN objective of this study is to investigate the efficiency of the physicochemical treatment process for removal of hazardous refractory wastewater from carpet industry. Characteristics of carpet industry wastewater in terms of COD, BOD, TSS were 60000, 110, 9800 mg/L. Their complete biodegradation is usually very slow as indicated from the immensely low value of BOD/COD, 0.002. High TSS promote the coagulation/flocculation in which coagulants such as ferric chloride, ferrous sulfate and flocculent are added to wastewater in order to destabilize the colloidal materials, eliminate as much as possible of suspended solids and organic materials. The results showed that ferric chloride (1.2g/L), flocculent (2mg/L) at pH 8 achieved COD removal efficiency of 97% whereas using ferrous sulfate (1.8 g/L), flocculent (2 mg/L) at pH 7 achieved 98% COD removal. Corresponding TSS removal values were 96 and 97%, respectively. Furthermore, lamellar sedimentation of the treated effluent followed by sand filtration upgrades the finally treated effluent for recycling inside the factory, the residual COD and TSS were 70 and 5mg/L respectively. The construction cost of the treatment unit (100 m^3/d) is about US$ 26000 and the running cost is about US$ 3300/year, providing a saving of about US$ 8064/year.

Keywords: Carpet refractory wastewater, Coagulation-flocculation treatments, Sand filtration, Construction and running costs.

Introduction

Carpet industry as one of the textile industries, generates many hazardous pollutants such as organic and inorganic matters, latex and dyes in addition to various proportions of non-biodegradable constituents. These industries discharge huge amounts of wastewater with highly colorized feature. They are growing rapidly causing many environmental problems, as a result of these facts, these industries are categorized as one of the most polluting industries [1–3].

The wastewater can cause serious environmental problems due to their high color, large amount of suspended solids, and high chemical oxygen demand [4]. As this wastewater has high load of organic contaminants, it is very hard to discharge into the biosphere before suitable treatment [5-7].

Carpet manufacturing process is composed of three main processes: extrusion, weaving and tufting. Polypropylene and polyethylene granules in addition to pigments are introduced to the extrusion process where yarns are the product of this process. Yarns are then woven in the weaving process producing carpets as an output of this process. To make the bottom layer of the carpet (substrate), latex, filler are added in what is so called tufting process whereby the carpet bottom layer is threaded into a fabric. This is the final process of producing carpets. The wastewater produced by the described processes comes from; mixing of washing tank, machines and floor washing. It is worth mentioning that huge amount of wastewater is produced throughout the carpet manufacturing processes. The elimination of pollutants found in carpet industry wastewater is presently of great concern, since their complete biodegradation is usually very slow and requires

*Corresponding author e-mail: iabdelhafiz@yahoo.com
Tel: 0020-12-74999938, Fax 0020-2-37484077, ORCID: 0000-0003-2567-8830
Received 14/9/2018; Accepted 1/11/2018
DOI: 10.21608/EJCHEM.2018.5191.1465

several days or weeks. There is no single process capable of adequate treatment of these wastewaters for reuse [4, 8].

Due to the high water consumption in the textile industry in general, carpet processing in particular, hybrid processes have been studied to treat textile wastewaters [8–11]. However, their application in an industrial plant becomes difficult due to the operation problems and to the costs. Chemical oxidation by ozone, or a combination of UV-radiation, ozone and H_2O_2, has great interest but cost still very high. Applications of membrane technologies in textile industries are not yet very common. Until now the reported applications are focused on the recovery of sizing agents from the de-sizing effluents and on the recovery of the dyes from the dyeing effluents by ultrafiltration [12, 13].

Regarding to Fenton process, due to the relatively high concentrations of ferrous sulfate and hydrogen peroxide which are required for the treatment, Fenton's treatments could be evaluated as non-economical for the large volumes of textile wastewater [14].

The biosorption processes are found to be cost effective for removal of heavy metals but in case of highly polluted wastewater with organic maters like in case of the rug and carpet industrial wastewater where the COD could reach some grams per liter, the removal of these loads of organics via the biosorption processes will be practically difficult [15, 16].

Jar-tests allow the evaluation of a treatment to reduce suspended, colloidal and non-settleable matter from water by chemical coagulation-flocculation followed by gravity settling [17]. Thus, these method are a valuable tool in wastewater treatment in relation to the economical factor [18]. The use of membranes in combination with physical-chemical processes is very interesting to produce water to be reused from the global effluent of the industry. The factors that limit their application are the management of the membranes retentate streams due to their high conductivities and the durability of the membranes due to fouling and concentration polarization [19, 20].

Chemical wastewater treatment relies on collecting suspended matter in untreated water together for further settling and for preparation of water for filtration [21].

Coagulation is summarized in three main steps, which are: Coagulation, Flocculation, and Sedimentation. Untreated wastewater may contain organic and inorganic matter as well as various proportions of non-biodegradable constituents. The function of coagulation is to remove these particles. Collides in wastewater are stabilized by negative electric charges on their surface, forcing them to repel each other. The particles repulsion inhibits their settling and retains them in suspension [22]. Thus, the equilibrium between the repulsive and attractive forces that the particles exert as they become close to each other makes the stability of the colloidal considerations. These charges assist clouds of counter-ions to form around the particles, giving rise to repulsive forces that inhibit aggregation and minimize the effectiveness of subsequent solid-liquid separation phases. Therefore, chemical coagulants are often added to suppress the repulsive forces of the particles. The three main types of coagulants are inorganic electrolytes (such as alum, lime, ferric chloride, and ferrous sulfate), flocculent with anionic or cationic functional groups [23].

The main objective of this study is to investigate the efficiency of the coagulation-flocculation treatment processes followed by sand filtration for removal of hazardous refractory wastewater from rug and carpet industry for reuse. Specific objectives are: evaluation of the physical-chemical treatment with jar-tests for carpet wastewater treatment, optimization of pH and coagulant and flocculent concentration for the treatment processes.

Experimental

This study was carried out in two steps. The first step consisted of the characterization of the collected wastewater samples. In the second step a physico-chemical treatment was applied to wastewater in order to reduce COD and TSS for compatible recycling limits.

Sampling collection and analysis

The carpet industry under investigations produces more than 36000 m^3/year of hazardous refractory wastewater. Composite wastewater samples representing the normal daily flow discharge from the end-off-pipe were collected. The samples were preserved in an ice box at a temperature of 4 ^{0}C and transferred directly to the laboratory for analysis. The analyzed parameters were; total suspended solids (TSS), kjeldahl nitrogen (TKN), and chemical oxygen demand (COD), biological oxygen demand (BOD). Oil&

Grease and all extracted materials by chloroform (O&G), hydrogen sulfides, total phosphorus (TP), phenol and cyanides. All the analyses, unless otherwise specified, were carried out according to the Standard Methods for the Examination of Water and Wastewater [24].BOD, or biochemical oxygen demand, is the measure of the oxygen consuming capabilities of organic matter biologically. Water with high BOD indicating the presence of biodegradable decomposing organic matter. COD was measured according to dichromate method 5210-D. BOD was measured according to 5-D BOD test method (5210-B). pH was measured using bench pH meter model Adwa AD 8000. TKN was measured using mercuric sulfate digestion method followed by titration method (4500-Norg). TP was measured according to the method (4500-C). Oil and grease were measured using the gravimetric partitioning method (5520-B). Total suspended solids were measured gravimetrically after sample filtration using GF/C paper method 2540-D. Total sulfides were measured according to method 4500-E in APHA 2017 [24].

Physico-chemical experiments

A multiple stirrer Jar-Test apparatus will be considered for the physicochemical treatment of the wastewater. Experiments were performed using Ferrous sulfate heptahydrate ($FeSO_4 \cdot 7H_2O$) and ferric chloride ($FeCl_3 \cdot 6H_2O$) (from Merck Company) and polyelectrolyte anionic flocculent of anionic polyacrylamide. Calcium oxide was used as a coagulant aid in chemical coagulation process. The following solutions were prepared and used in the experiments: CaO (20 %), HCl (10%), ($FeSO_4 \cdot 7H_2O$) and ($FeCl_3 \cdot 6H_2O$) (30 %), anionic polymer (0.1 %).

The optimum dose and pH of the coagulant were investigated using jar test procedure. One liter of wastewater sample was transferred to each jar. The samples were rapidly mixed at a paddle speed of 250 rpm, and coagulants were added then finally, polymer was instantaneously added. The rapid mixing was for 1 min., followed by slow mixing for 20 min. at 20 rpm and then settling for 1 h. The supernatant was withdrawn by means of a suction device for analysis. Lamellae sedimentation followed by sand filtration will be carried out for recycling of the treated wastewater [25].

Sand filter

The effluent from the Lamellae sedimentation unit is fed to the sand filter at top side via equidistance nozzles to ensure uniform distribution. The function of the sand filter is polishing the effluent such that treated wastewater can be used for washing process in the factory. The sand filter was made from Perspex material with 110 litre capacity. Main dimensions of: 60 cm x 40 cm w x 46 cm d. Three layers of equal depth 0.15 m each constitute the sand filter content. Top layer of gravel bed with particle size from 0.3 mm to 0.45 mm, middle layer of fine sand with size between 0.15 and 0.2 mm, bottom layer of gravel bed with particle size from 0.3 mm to 0.45 mm. Hydraulic surface Loading rate of sand filter ranged between 0.25 and 1.5 $m^3/m^2/day$, this type belongs to slow sand filters [26, 27].

Results and Discussion

Factory Baseline

A factory, located in an industrial city, North Cairo, Egypt. The factory produces a huge amount of rug and carpet and has an average consumption of water, 36000 m^3 per year. Wastewater is produced from production lines and cleaning operations of equipment's and floors as described in Fig. 1. This wastewater is usually milky in color containing finely dispersed solids of macromolecules called collides. As this wastewater has high load of organic contaminants

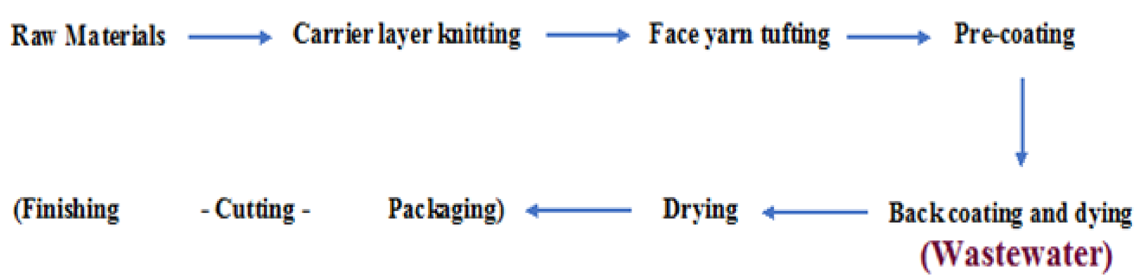

Fig. 1. Schematic diagram of Carpet industry wastewater sources.

then it is very hard to reuse the wastewater or to discharge into the public sewerage system before treatment [5].

Raw wastewater characteristic

Five composite samples from the end-off-pipe of the factory were collected for physico-chemical analysis. The characteristics of this wastewater indicated its containment of refractory and non-biodegradable organic substrates. This is obvious from the average values of BOD (110 mg/L) and COD (60000 mg/L), (Table 1) and from the ratio of BOD/COD which was less than 0.002 [28]. The oil & grease with an average value of 7155 mg/L, average value of TSS concentration was 9800 mg/L. Therefore, as a result of the high concentration of TSS, chemical treatment using coagulation-flocculation process followed by sedimentation and sand filtration were investigated intensively.

TABLE 1. Carpet and rug industry wastewater characteristics.

Parameter	Unit	Min.	Max.	Average*	MD44/2000
pH	--	4.5	4.9	4.7±0.2	6-9.5
Chemical Oxygen demand(COD)	mg/L	58885	64385	60000±243	1100
Biochemical oxygen Demand(BOD_5)	mg/L	104	142	110±16	600
Total Suspended Solids(TSS)	mg/L	8723	9941	9800±105	800
Total Kjeldahl Nitrogen(TKN)	mg/L	365	443	422±32	100
Oil and Grease	mg/L	6362	7554	7155±85	100
Settleable Solids at 30 minutes	mL/L	1.2	1.7	1.2±0.2	15
Total Sulfides	mg/L	38	55	41±6	10
Total Phosphorus(TP)	mg/L	8.0	11.4	10.7±1.6	25
Phenols	mg/L	ND	ND	ND	0.05
Cyanides(CN)	mg/L	ND	ND	ND	0.2

*Average of 5 samples ND: Not detected

MD 44/2000: Egyptian permissible limits for wastewater discharge into sewerage system [29].

Treatment of wastewater using coagulation-flocculation process

Coagulation/flocculation is a core and usually the first unit process in water and industrial wastewater treatment processes [30]. It is the most important process for the removal of suspended particles. This process occurs through destabilizing the balanced colloidal particles then they agglomerate into larger flocks and settle [31]. Bench scale chemical coagulation process was preferred utilizing a Jar test procedure to get the appropriate pH value and coagulant dose required for the best removal of the contaminants. For the favored removal of pollutants ferrous sulfate and ferric chloride aided with polymer has been investigated for this type of wastewater.

Effect of pH on COD removal by various coagulants

In order to study the effect of pH on the COD removal, eight tests were carried out for each coagulant $FeCl_3$ and $FeSO_4$ Different pH values were examined (2, 3, 4, 5, 7, 8, 9, 10) at constant suggested doses of coagulants 0.75 g/L, and flocculent (anionic polymer), 2.5 mg/L. Figure 2 depicts the results of the residual COD for the two coagulants used. As can be seen, at acidic pH,a minimal removal of COD were achieved (around 20%). A considerable decrease in the residual COD of the contaminated solution is observed when raising the pH which reaches optimum values of 8 and 7 for Ferric chloride and ferrous sulfate respectively.

In case of using $FeCl_3$, at the optimum working pH value, 8, concentration of ferric hydroxide $Fe(OH)_3$ is very high when compared to other iron salts. Thus the principal treatment phenomena of COD are the precipitation and adsorption of contaminants onto the $Fe(OH)_3$ flocks formed. For ferrous sulfate, the optimum pH for COD removal

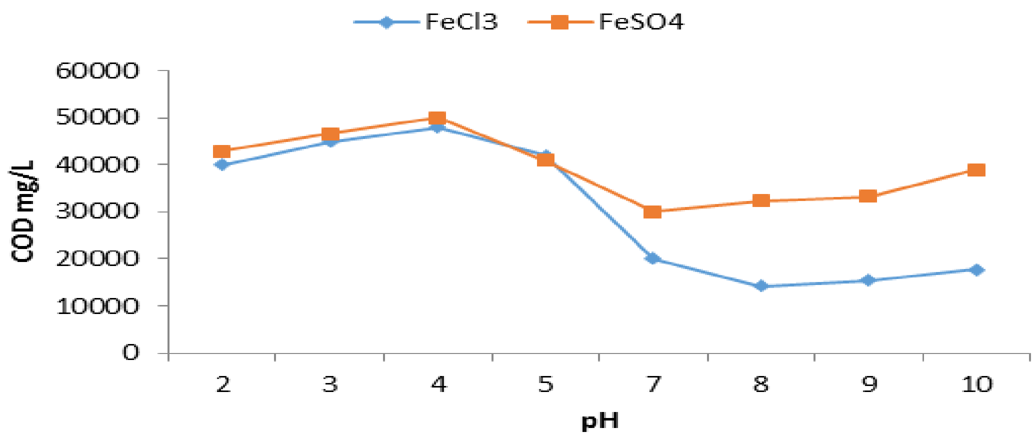

Fig. 2. Effect of pH on the removal of COD using $FeCl_3$ and $FeSO_4$ coagulants.

was found to be 7. At this pH, the presence of Fe^{2+} and $Fe(OH)^+$ is maximum and the COD removal takes place by charge neutralization and sweep flocculation [32].

Determination of optimum coagulant dosage

The results of the effects of different dosages of $FeCl_3$ and $FeSO_4$ as primary coagulants on the removal of COD from the wastewater at the optimum pH of 8 &7 respectively, and polymer constant dose of 2.5 mg/L are presented in Fig. 3 and 4. The removal efficiencies of COD increased rapidly up to 93.7 and 93.3% at 1.2 and 1.8 g/L for $FeCl_3$ and $FeSO_4$ respectively.

This may be attributed to the following reasons: the increase of adsorptive surface due to increase of ferric hydroxide precipitates and the formation of flocks and acid anion complexes by electrostatic interaction. The complexes led to an enhancement of colloids removal, whereas between 1.2 to 1.8 g/L for $FeCl_3$ and 1.8 to 3 g/L for $FeSO_4$ the removal of COD increased slowly. Addition of the coagulant above 1.2 g/L for $FeCl_3$ and 1.8 g/L for $FeSO_4$ caused the removal efficiency to appear constant. These results are higher than those obtained by Mahmoud, 2009 [33] who reported that the maximum removal of COD was 62.3% when he used 0.2 g/L $FeCl_3$.

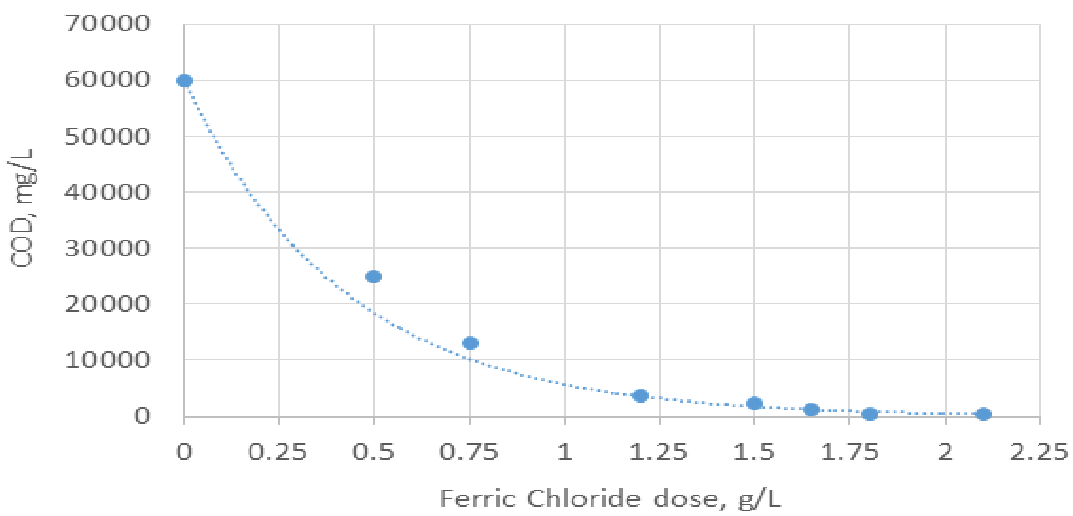

Fig. 3. Effect of different ferric chloride doses on COD removal at constant pH and polymer dose.

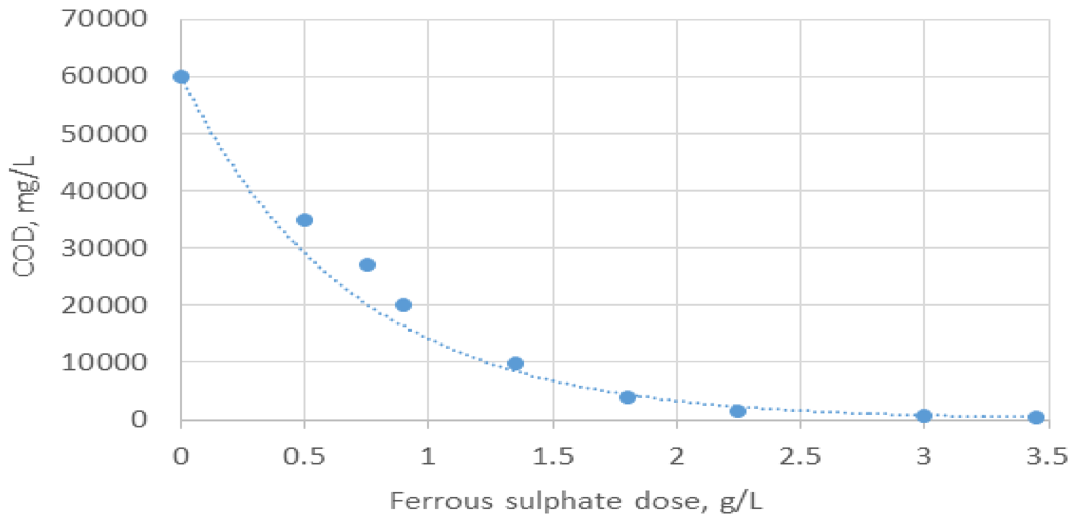

Fig. 4. Effect of different ferrous sulfate doses on COD removal at constant pH and polymer dose.

Also, these results are slightly higher than those obtained by Nabi et al. 2007 [34] who reported that the maximum removal of COD was 90% when he used 0.4 g/L $FeSO_4$.

Determination of optimum polymer dosage

Several studies in the treatment of industrial wastewater investigated the use of both polyelectrolyte (as a coagulant aid or flocculent) and chemical coagulant [35]. In this research the dose of polyelectrolyte (anionic polyacrylamide) was changed from 0.5 to 3 mg/L at constant doses of $FeCl_3$, 1.2 g/L and $FeSO_4$, 1.8 g/L at pH 8 and 7, respectively. In order to examine the optimum dose of the polyelectrolyte, the percentage removal of COD was considered. From Fig. 5 and 6, it can be seen that removal of COD reached 70 and 55.8% during the use of 1 mg/L polyelectrolyte for both coagulants. The removal of COD was slowly increased to 98.8 and 97.9% when the dose of the polyelectrolyte was increased to 2 mg/L for both $FeCl_3$ and $FeSO_4$ respectively. Further increase in the dose of the polyelectrolyte did not cause further increase in the percentage removal of

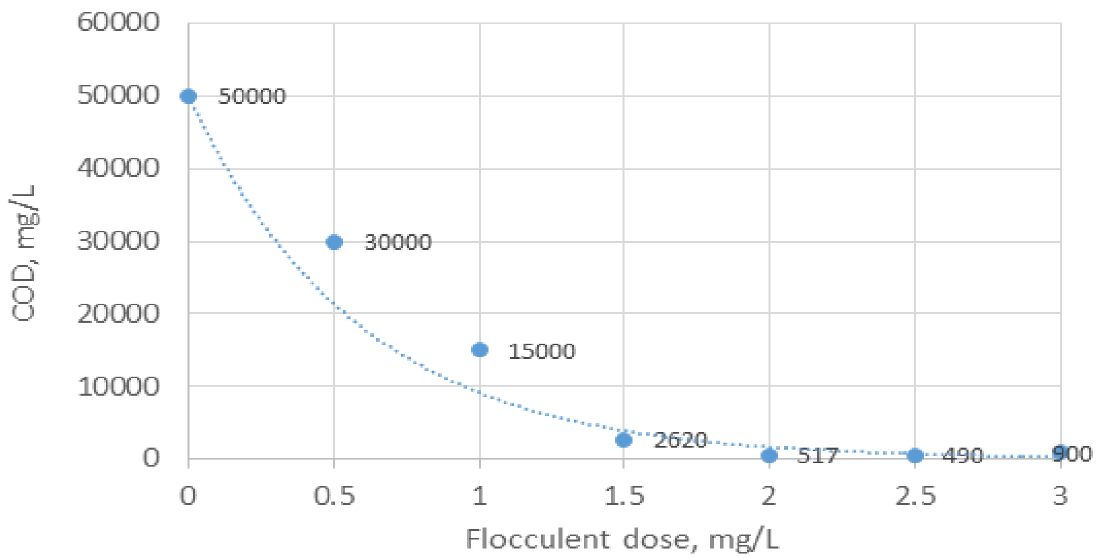

Fig. 5. Effect of different polymer doses on COD removal using ferric chloride.

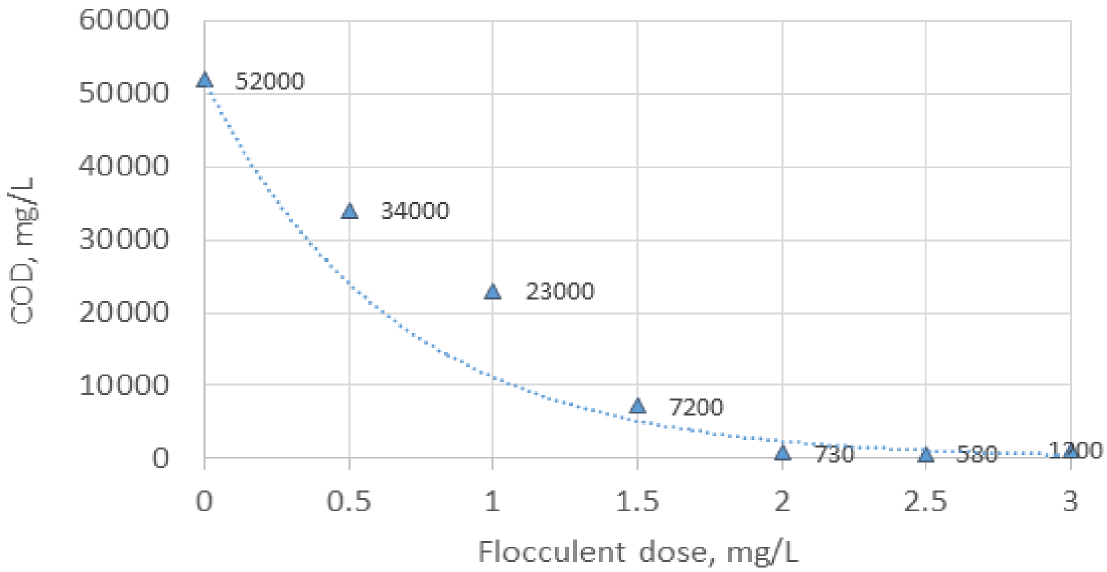

Fig. 6. Effect of different polymer doses on COD removal using ferrous sulfate.

COD. Thus, the optimum dose for both $FeCl_3$ and $FeSO_4$ was 2mg/L. According to Nabi et al., 2007, the optimum dose of polymer was 1 mg/L when using 0.2 g/L $FeSO_4$, a 90% removal of COD was achieved [34].

Efficiency of coagulation-flocculation process for the treatment of the wastewater

The results presented in Fig. 7 and Tables 2&3 show that the quality of treated effluent agrees with the national public sewerage law. In the case of $FeCl_3$, the concentration of COD, TSS, TKN, TP and O & G were reduced from 60000 to 520, 9820 to 54, 422 to 9.5, 41 to 0.9 and 7155 to 13.5 mg/L, respectively. The corresponding removal efficiency was 97, 96, 95, 88 and 96%, respectively. In the case of $FeSO_4$ the concentration of COD, TSS, TKN, TP and O & Gwere reduced from 60000 to 425, 9800 to 24, 422 to 8.4, 41 to 1.2 and 7155 to 12 mg/L, respectively. The corresponding removal efficiency was 98, 97, 96, 87 and, 97%, respectively.

These removals are slightly higher than those obtained by Nabi et al., 2007 who reported that TSS removals reached 90 % [34].

Analysis of the produced chemical sludge indicated a production of 140 L/m^3. This volume of sludge has 1.9 kg of dry solid with 40% organic matter. The sludge volume index (SVI) was 74 ml/g which indicates very good settling properties. Characteristics of the treated effluent using $FeCl_3$ and $FeSO_4$ agree with the national permissible limits for discharging into the sewerage system (Tables 2 and 3). Based on the laboratory results a schematic diagram of the chemical treatment system is proposed (Fig. 8).

Efficiency of post treatment using the sand filter for recycling the treated effluent

Using some tertiary treatment processes as sand filter, the quality of the produced effluent is improved [36]. The sand filter is a relatively simple, inexpensive and environmentally-friendly treatment method used for purifying wastewater in three distinct ways; filtration, chemical sorption and assimilation.

For sustainable and economic factors, recycling of the treated wastewater is an important issue. The coagulation-flocculation process is followed by the lamella sedimentation and the treated effluent was subjected to sand filtration for further removal of COD and TSS. The physico-chemical analysis of the finally treated effluent is illustrated in Tables 2&3. The characteristics of the treated effluent in terms of residual COD and TSS were about

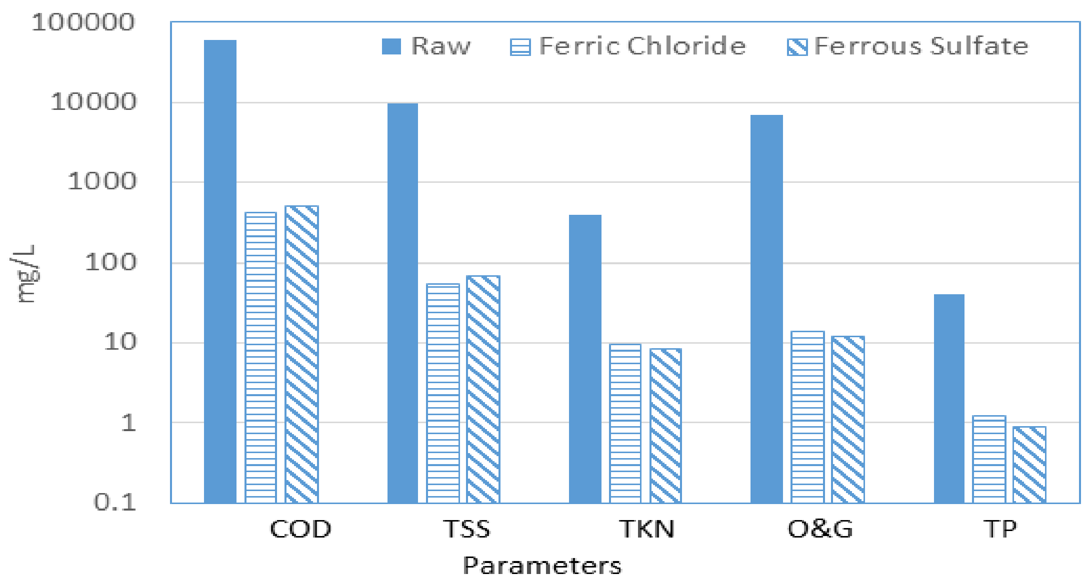

TABLE 2. Characteristics of the finally treated carpet and rug wastewater coagulation using $FeCl_3$ aided with polymer at operating conditions.

Parameter	Unit	Raw Average*	Coagulation-Flocculation	Sand filtration	MD 44/2000
pH	--	4.7±0.2	8.6±0.1	٨.١	6-9.5
Chemical Oxygen demand (COD)	mg/L	60000±243	520±16	75	1100
Biochemical Oxygen Demand (BOD_5)	mg/L	110±16	15	9	600
Total Suspended Solids (TSS)	mg/L	9800±105	54±8	٧	800
Total Kjeldahl Nitrogen (TKN)	mg/L	422±32	9.5±0.3	6	100
Oil and Grease (O&G)	mg/L	7155±85	13.5±1.4	8	100
Total Phosphorus (TP)	mg/L	41±6	0.9±0.1	0.4	25

*Average of 5 samples

MD44/2000: National permissible limits for wastewater discharge into sewerage system

TABLE 3. Characteristics of the finally treated carpet and rug wastewater Coagulation using $FeSO_4$ aided with polymer at optimum operating conditions.

Parameter	Unit	Raw Average*	Coagulation-Flocculation	Sand Filtration	MD 44/2000
pH	--	4.7±0.2	7.8±0.2	7.7	6-9.5
Chemical Oxygen demand (COD)	mg/L	60000±243	425±14	70	1100
Biochemical oxygen Demand (BOD_5)	mg/L	110±16	14	7	600
Total Suspended Solids (TSS)	mg/L	9800±105	24±6	٥	800
Total Kjeldahl Nitrogen (TKN)	mg/L	422±32	8.4±0.3	6	100
Oil and Grease (O&G)	mg/L	7155±85	12±1.1	7	100
Total Phosphorus(TP)	mg/L	41±6	1.2±0.1	0.5	25

*Average of 5 samples
MD44/2000: National permissible limits for wastewater discharge into sewerage system

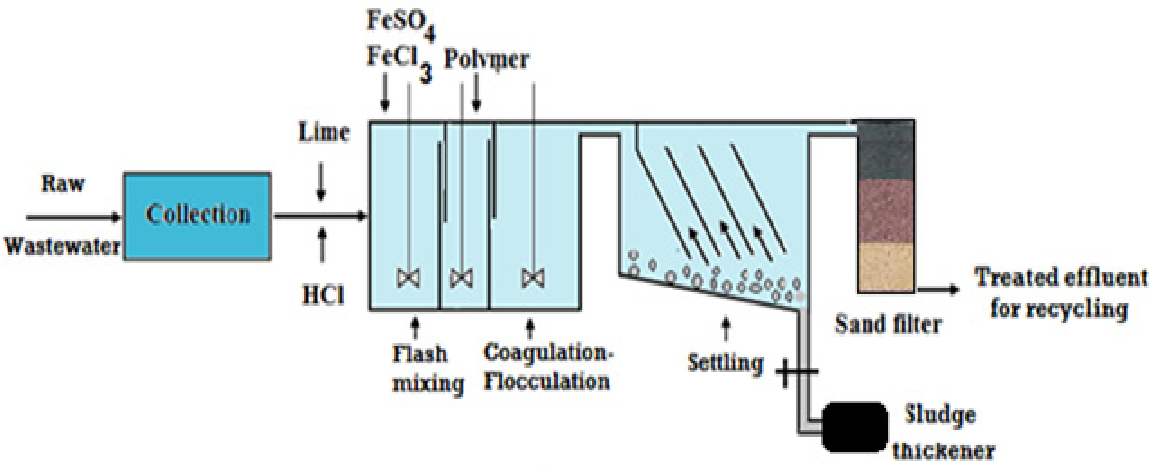

Fig. 8. Schematic diagram of the chemical treatment system.

75 mg/L and 7 mg/L which allow the treated effluent for recycling inside the factory. The removal of COD and TSS were more than 80% which near to the results obtained by Assayed et al. (2014) [37].

Economic evaluation of the proposed treatment system

The economic evaluation is made for the proposed system that is capable of treating 100 m^3/d. The economic evaluation is based on the construction, operation and maintenance costs.

The construction cost evaluation considers the following

The system is to be constructed from mild steel coated internally with a protective coating layer. The construction cost includes the cost of the following components: Materials used in construction, Pumps for pumping wastewater from the collection sump to the treatment system, media used inside the sand filter, piping for the system influent and effluent. The construction cost of the treatment plant shown in Fig. 8 is around US$ 26000.

The operation and maintenance costs evaluation consider the followings

Power consumption (electricity) required for system operation and for pumping, Labours required for system operation and maintenance, spare parts, cleaning, changing of media every 3 years and removal of sludge from the system. The running cost is about US$ 3300/year.

Assuming 20 years depreciation and 100 m^3 of treated wastewater/day hence the total construction cost per m^3 of treated wastewater will be US$ 0.036. In addition, the daily costs of operation and maintenance of the proposed system will be US$ 0.09 /m^3 of wastewater.

The total cost (construction and operation) for treating wastewater for recycling in the factory will be US$ 0.126/m^3. As the cost of municipal water is US$ 0.35/m^3. Thus, this treatment and recycling system is estimated to save about US$ 8064/year since the saving is US$ 0.224/m^3.

Conclusion

Wastewater characteristics of carpet industry which represents one sector of the textile industry determine the adequate treatment system. The wastewater generated from carpet industries is characterized by high concentration of COD, TSS and low BOD values. Their complete biodegradation is usually very slow as indicated from the very low BOD/COD ratio (0.002), requiring several days or weeks. Due to high concentration of suspended solids, coagulation-precipitation was selected as feasible solution for the treatment. Chemical coagulation process using either ferric chloride aided with polymer or ferrous sulfate aided with polymer produced effluent characteristics complying with the National permissible limits for wastewater discharge into public sewerage system. However, the treated effluent by ferric chloride was found to be more favorable for economic reasons. Further application of lamella sedimentations followed by sand filtration allows the treated effluent for recycling inside the factory. This treatment and recycling system is estimated to save about $ 8064/year.

References

1. Verma Akshaya Kumar, Rajesh Roshan Dash, Puspendu Bhunia, A review on chemical coagulation/flocculation technologies for removal of colour from textile wastewaters *J. Environ. Manag.* **93**, 154-168 (2012).

2. Gupta S., Impact of Effluent of Carpet Industries Containing Municipal Sewage (Khamaria – Sant Ravidas Nagar Bhadohi, Uttar Pradesh, India) On Germination and Seedling Growth of Barley and Gram-with special reference to Wastewater *Treatment Method Ultra Chemistry* **8**(1), 105-116 (2012).

3. Holkar C. R., Jadhav A. J., Pinjari D. V., Mahamuni N. M., Pandit A. B., A critical review on textile wastewater treatments: Possible approaches, *Journal of Environmental Management* **182**, 351-366 (2016).

4. Kim, T.-H., Park, C., Yang, J., Kim, S., Comparison of disperse and reactive dye removals by chemical coagulation and Fenton oxidation. *J.Hazard. Mater.* **B112**, 95–103 (2004).

5. El-Shamy A.M., Abdelfattah I., Elshafey O. I., Shehata M.F., Potential removal of organic loads from petroleum wastewater and its effect on the corrosion behavior of municipal networks, *J. Environ. Manag.* **219,** 325-331 (2018).

6. El-Dafrawy Sh. M., Youssef H. M., Toamah W. O. and El-Defrawy M. M., Synthesis of Nano-CaO Particles and Its Application for the Removal of Copper (II), Lead (II), Cadmium (II) and Iron (III) from Aqueous Solutions, *Egypt. J. Chem.* **58**(6), 579-589 (2015).

7. Morsi R.E., Al-Sabagh A.M., Moustafa Y.M., El Kholyand S.G., Sayed M.S., Mercury Uptake Capacity of Chitosan: Kinetic and Isotherm Study, *Egypt. J. Chem*. **57**(5), 411–422(2014).

8. U. Altinbas et al., Treatability study of wastewater from textile industry, *Envir. Technol.*, **16,** 389–394 (1995).

9. Coloma J.M., Optimización de las depuradorasfísico-químicas, Revista de QuímicaTextil, **137**, 31–40 (1998).

10. Orhon D. et al., A scientific approach to wastewater recovery and reuse in the textile industry, *Water Sci. Technol.*, **43**(11), 223–230 (2001).

11. Balcioglu I.A. and Arslan I., Partial oxidation of reactive dyestuffs and synthetic textile dye-bath by the O3 and O3/H2O2 processes, *Water Sci. Technol.*, **43**(2), 221–228 (2001).

12. Crespí M., Aplicación de los Procesos de Membranaen la Industria Textil in Apuntesdel Curso de Membranas y Medio Ambiente, Universidad Politécnica de Cataluña, Barcelona, (1992).

13. ASTM Standard practice for coagulation flocculation jar test of water. *American Society for Testing and Materials* (1995).

14. Gulkaya I., Surucu G. A., Dilek B. F., Importance of H2O2/Fe2+ ratio in Fenton's treatment of a carpet dyeing wastewater, *J. Hazard. Mat.* **B136**, 763–769 (2006).

15. Abdelfattah F. Al Sayed and Almedolab A., Removal of heavy metals from wastewater using corn cob,*Res. J. Pharm. Biol. Chem. Sci*., **7**(2), 239-248 (2016).

16. Abdelfattah I., Adel A.I., Fathy Al Sayed, Almedolab A., Aboelghait K.M., Biosorption of heavy metals ions in real industrial wastewater using peanut husk as efficient and cost effective adsorbent, *Environmental Nanotechnology, Monitoring & Management* **6**, 176–183 (2016).

17. Marín R., Jar-test en el tratamiento de aguas: unavaliosaherramienta. *Tecnología del agua,* **181**, 25–32 (1998).

18. Hart O.O., Groves G.R., Buckley C.A. and Southworth B., A guide for the planning, design and implementation of wastewater treatment plants in the textile industry. Part one: Closed loop treatment / Recycle system for textile sizing / desizing effluents. *Pretoria* (1983).

19. Belfort G., (Ed.) Synthetic Membrane Proceses. Academic Press, Inc., New York (1984).

20. M. Mulder, Basic Principles of Membrane Technology. Kluwer Academic Publishers, 1992

21. Nasr F.A., Doma H.S., El-Shafai S.A. and Inas A. T., Management of Industrial Wastewater (Case Study). *Applied Sciences Research*, **8**(6), 3004-

3011 (2012).

22. Bertanza G., Collivignarell C. and Pedrazzen I. R., The role of chemical oxidation in combined chemical-physical and biological processes: experience of industrial wastewater treatment. *Wat. Sci. and Technol.*44, 109-116 (2001).

23. Nasr F.A., Doma H.S., Abdel-Halim H.S. and El-Shafai S.A., Chemical Industry Wastewater Treatment, *Int. Journal of TheEnviornmnetalist*, **27**, 275-286 (2007).

24. APHA, *Standard Methods for the Examination of Water and Wastewater,* 23rd edn. Prepared and published jointly by: American Public Health Association, American Water Works Association and Water Environment Federation, APHA 800 l Street, NW, Washington, DC 20001-3710 (2017).

25. Metcalf Eddy, Inc., *Wastewater Engineering Treatment and Reuse,* Fourth Edition, McGrawHill, New York (2003).

26. Zipf M. S., Pinheiro I. G. and Conegero M. G., Simplified grey water treatment systems: Slow filters of sand and slate waste followed by granular activated carbon. *Journal of Environmental Management,* **176**, 119-127 (2016).

27. Zheng X., Mehrez R., Jekel M. and Ernst M., Effect of slow sand filtration of treated wastewater as pre-treatment to UF. *Desalination*, **249**(2), 591-595 (2009).

28. Nasr F. A., Abdelfattah I., Shana A. M. and Abo-Aly M.M., Fenton Oxidation Process of Refractory Organics in Gas Processing Wastewater. *Egypt. J. Chem.* **59**(2), 241- 252 (2016)

29. MD44/2000 Ministerial Decree No. 44 on the amendment of the implementing regulation of low No. 93/1962 for industrial wastewater discharge into public sewerage network, art. 14. Ministry of housing, utilities, and urban communities, Egypt (2000).

30. El-Awady M. H., Abdelfattah I. and Abo El-Magd A., Reliable Treatment of Petroleum Processing Wastewater Using Dissolved Air Flotation in Combination with Advanced Oxidation Process, *Egypt. J. Chem.* **58**(6), 609– 624 (2015).

31. Menkiti M.C, Nwoye C.I., Onyechi C.A. and Onukwuli O.D., Factorial Optimization and Kinetics of Coal Washery Effluent Coag-Flocculation by Moringa Oleifera Seed Biomass, *Advances Chemical Engineering and Science*, **1**, 125-132 (2011).

32. Stephenson R.J. and Duff S.J.B., Coagulation and precipitation of a mechanical pulping effluent. I. Removal of carbon, colour and turbidity. *Water Res.* **30**(4), 781–792 (1996).

33. Mahmoud E.K., Chemically enhanced primary treatment of textile industrial effluents. *Polish Journal of Environ. Stud.* **18**(4), 651-655 (2009).

34. Nabi B.G.R., Torabian, A., Ehsani, H. and Razmkhah N., Evaluation of industrial dying wastewater treatment with coagulants and polyelectrolyte as a coagulant aid. *Iran Environ. Health. Sci. Eng.,* **4**(1), 29-36 (2007).

35. Amuda O.S., Amoo I.A. and Ajayi O.O., Performance optimization of coagulant/flocculant in the treatment of wastewater from a beverage industry. *Hazard. Mater,* **129**, 69–72 (2006).

36. Latrach L., Ouazzani N., Masunaga T., Hejjaj A., Bouhoum K., Mahi M. and Mandi L., Domestic wastewater disinfection by combined treatment using multi-soil-layering system and sand filters (MSL–SF): A laboratory pilot study. *Ecological Engineering,* **91**, 294-301 (2016).

37. Assayed A., Chenoweth J., Pedley S., Drawer compacted sand filter: A new and innovative method for on-site grey water treatment. *Environ Technol.* **35**(17-20), 2435-2446 (2014).

معالجة مياه الصرف الصناعي لصناعة السجاد بالطرق الفيزيو كيميائية منخفضة التكاليف لاعادة الاستخدام

فايزة علي نصر، ابراهيم عبد الفتاح، عبد الرحمن شانة
قسم بحوث تلوث المياه - المركز القومي للبحوث - الجيزة - مصر.

الهدف الرئيسي من هذه الدراسة هو استخدام طرق المعالجة بالتخسير والترويب في ازالة الملوثات صعبة التحلل البيولوجي من مياة الصرف الصناعي الناتجة من صناعة السجاد والموكيت.حيث أن قيم ال (BOD/COD) منخفضة جدا حيث قدرت ب (0.002) وقيم المواد العالقة الكلية عالية وقد قدرت ب (9800 ملجم/لتر). ونظرا للقيم المرتفعة لتركيزات المواد العضوية الضارة (60000 ملجم/لتر) مع انخفاضا ملحوظا للمواد العضوية القابلة للتحلل البيولوجي (BOD) حيث قدرت ب (110 ملجم/لتر) فكان من الصعوبة استخدام الطرق البيولوجية في المعالجة. نظرا لارتفاع قيم تركيزات المواد العالقة فقد تم استخدام كلوريد الحديديك وكبريتات الحديدوزوكذلك اضافة البوليمر للمساعدة في سرعة الترسيب والفصل. أظهرت النتائج أنه باضافة كلوريد الحديديك بتركيز (1.2 جم/لتر)، والبوليمر بتركيز (2 ملجم / لتر) عند الرقم الهيدروجيني (8) حققت كفاءة إزالة لل(COD)حوالي 97% بينما عند استخدام كبريتات الحديدوز بتركيزات (1.8 جم / لتر)، والبوليمر بتركيز (2 ملجم / لتر) عند الرقم الهيدروجيني (7) حقق نسبة ازالة وصلت 98% لل (COD) وكانت نسبة إزالة المواد العالقة الكلية (TSS 96 % و97 % على التوالي.علاوة على ذلك، فإن الترسيب بالالواح المائلة للمياه الناتجة من المعالجة الكيميائية متبوعًا بالترشيح الرملي يقوم بتحسين نسب ازالة ال (COD) حيث وصلت تركيزاتها المتبقية حوالي 75 ملجم/ لتر وكذلك ال (TSS) بلغت تركيزاتها المتبقية في المياه المعالجة الى 7 ملجم/لتر مما يسمح باعادة استخدام المياه المعالجة في غسيل المعدات ونواتج التصنيع داخل العمليات الصناعية مما يوفر 8064 دولار أمريكي في السنة (سعر المتر المكعب من المياه البلدية حوالي 0.25 دولار أمريكي). تم حساب تكلفة إنشاء وحدة المعالجة وقد بلغت حوالي 26000 دولار أمريكي وتكلفة التشغيل بلغت حوالي 3300 دولارأمريكي في السنة.