STUDY FOR INDUSTRIAL WASTEWATER TREATMENT USING SOME COAGULANTS

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ABSTRACT

The motivations for treatment of wastewater are manifold. Treatment and reuse of wastewater conserves the supply of freshwater and this presents clear advantages with respect to environmental protection. The main objective of this paper was to perform a preliminary comparative study between some coagulants on the removal of suspended solids and organic matter from mixed industrial wastewater. Samples were collected from the inlet of 10th of Ramadan City stabilization ponds, Egypt. The 10th of Ramadan City, as one of the major industrial cities in Egypt, suffer from serious environmental problems arise from the flooding of polluted wastewater to the Shabab Canal and Wady El Waten Drain.

Standard jar test with minor modification was used in the laboratory experiment. The procedures included rapid mixing, followed by slow mixing and settling. Supernatant was taken for determination of transitivity and chemical oxygen demand (COD) tests. The coagulants used included aluminum sulfate, ferric sulfate, lime, and ferric chloride with wide dosages range up to 250 mg/l. The best transmittance of treated wastewater was 100% with the use of alum and ferric chloride coagulant. It was found that the aeration of the coagulant and settled samples improved the COD removal efficiency than that the samples were not coagulated by about 41%.

Keywords: Industrial Wastewater, Coagulation, Flocculation, Sedimentation, Aeration, BOD, COD, pH

INTRODUCTION

There are two sewerage systems in the 10th of Ramadan city. The first system is combined (domestic/industrial) system that serves the first two stages of the city. This system goes through gravity and pumping stations to the first and the second stabilization ponds. The industries within these two stages include panting factories, food factories, textile, and chemical industry. The second system is separate system (for industrial wastewater), mainly for industrial wastewater from the heavy industrial areas. This system is directed to the third pond. The factories within this area include food processing, dye and textile industry, glass factories, and oil industry. Most of the factories violating the law (Decree 22, 2000) and do not apply any wastewater treatment for their liquid effluents.

There is a primary treatment plant (mechanical) followed by aerated lagoons that designed to receive the combined domestic / industrial wastewater from the first and the second stages of the city. The final effluent of the plant was planned to be used for agricultural use. There are about 465 hectares close to the three ponds that are in use for storage and evaporating the wastewater instead of tree planting as planned.

One of the famous treatment methods to reduce suspended solids and turbidity is the coagulation and flocculation. Coagulation uses salts such as aluminum sulfate (alum) or ferrous of ferric (iron) salts, which bond to the suspended particles, making them less stable in suspension, i.e., more likely to settle out. Flocculation is the binding or physical enmeshment of these destabilized particles, and results in flocs that is heavier than water, which settles out in a clarifier.

Hardam Singh Azad, 1996 stated that removal of very small particles by gravity sedimentation requires excessively long retention periods. Typically these solids are bacteria, viruses, colloidal organic and fine mineral. Chemical treatment of wastewater containing these solids results in the precipitation of chemical agents which cause flocculation and rapid settling.

In addition to solids removal, chemical treatment can help the reduction of organic pollution. A study was made to determine the effectiveness of various coagulants on the removal of organic pollutants from food wastewater, *"http://www.allbusiness.com/legal/laws-government-regulations-environmental/507260-1.html"*.

Standard jar test was used in the laboratory experiment. The procedures included one minute for rapid mixing, followed by 30 minutes of slow mixing and one hour settling. Supernatant was taken for determination of turbidity and TOC (total organic carbon) tests. Turbidity was measured by turbidity meter and TOC was determined by TOC analyzer, potato wastewater, sugar wastewater, and combined potato/sugar wastewater.

The experimental parameters used in this study including three organic strength of wastewater and types and dosage of coagulant. Three organic strength of food wastewater consisted of 50, 125 and 200 mg/L TOC. The coagulants used included aluminum sulfate, ferric sulfate, and ferric chloride with dosages of 2, 4, 6, 8, and 10 mg/l. The lowest turbidity of treated wastewater was 2, 10, and 25 TU (turbidity unit) with aluminum sulfate, ferric sulfate, and ferric chloride as coagulant. It was found that the low organic strength wastewater had higher turbidity removal efficiency than the medium and high organic strength wastewater. The highest percentage of TOC removal for aluminum sulfate, ferric sulfate, and ferric chloride were: 89, 88, and 95%, respectively. The results of this study showed that the ferric chloride had the best TOC removal efficiency, and the aluminum sulfate had the highest rate of turbidity removal among the three types of coagulants used in the study. The low organic strength wastewater had a better TOC and turbidity removal efficiencies than the medium and high organic strength wastewater. The general trend indicated that as the organic strength of wastewater increased the removal efficiency of TOC and turbidity decreased.

Ho et al., 2009 studied coagulation and flocculation process with a standard jar test procedure with rapid and slow mixing of a kaolin suspension (aluminum silicate), at 150 rpm and 30 rpm, respectively, in which a cation $Al^{(3+)}$, acts as a coagulant and pectin acts as the flocculent and found that maximum flocculating activity and turbidity reduction are in the region of pH greater than 3, cation concentration greater than 0.5 mM, and pectin dosage greater than 20 mg/L, using synthetic turbid wastewater within the range. The flocculating activity for pectin and turbidity reduction in wastewater is at 99%.

Xu et al, 2009 investigated the feasibility of ferric coagulant recovery from chemical sludge and its recycle in chemically enhanced primary treatment (CEPT) and found that the efficiency of coagulant recovery had a linear relationship with sludge reduction. Experiments verify that it would be a sustainable and cost-effective way to recover ferric coagulant from coagulation sludge in water treatment and chemical wastewater treatment and then recycle it to CEPT, as well as reduce sludge volume.

Rubi et al, 2009 studied treatment of wastewater discharged from four car washes by sedimentation and coagulation. The effect of the coagulants Servical P (aluminum hydroxychloride), Servican 50 (poly (diallyldimethyl ammonium chloride)), aluminum sulfate and ferric chloride was evaluated. The achieved removal using sedimentation was of 82%, 88% 73% and 51% for oils, total suspended solids, COD, and turbidity, respectively. In the treatment by coagulation we achieved average efficiencies nearly to 74% for COD removal, greater than 88% in the case of total suspended solids removal and 92% in the case of turbidity and except the performance of Servican 50 greater than 90% in oil removal.

Hardar et al., 2009 studied the treatment of tannery wastewater through coagulation-flocculation-sedimentation. Alum was used as coagulant with cationic and anionic polymers as coagulant aid. The results were compared with those when alum was used alone for the treatment. The comparison revealed that the use of coagulant aid reduced sludge volume by 60-70% and cost of chemicals by 50% for comparable removal efficiencies.

Sriwiriyarat et al., 2009 studied the waste activated sludge (WAS) as a coagulation aid in the coagulation-flocculation process with ferric chloride or aluminum sulfate as a coagulant for the treatment of wastewater collected from the aforementioned industry. Without the WAS addition, the concentrations of 800 mg/L aluminum sulfate at the optimum pH value of 8 and 2208 mg/L ferric chloride at the optimum pH value of 12 were the optimum chemical dosages. It appears that aluminum sulfate was more effective than ferric chloride based on the chemical dosage and removal efficiency. The addition of 200 mg/L was sufficient to reduce the optimum dosages of both chemicals by 200 mg/L.

Haydar et al., 2009 performed a study to evaluate the efficiency of cationic polymers as a suitable replacement of metal salts for the treatment of a local tannery wastewater. Eleven cationic polymers of varying molecular weights (MW) and charge densities (CD) were examined using jar test apparatus. The results demonstrated that treatment of tannery wastewater with cationic polymers is a viable and economical option when compared with metal salts.

The aim of the present study is to investigate the optimum coagulant dose and type of some coagulants to be used to reduce the strength of the wastewater and improve its biological treatment.

MATERIAL AND METHODS

The experimental works was carried out in a standard Jar test set for the coagulation and sedimentation study, and then in 2 liters conical flasks for the aeration. The settling time was considered only 30 minutes instead of one hour. Raw samples, chemically precipitated samples and aerated samples have been analyzed for transmittance (turbidity) and COD. COD was measured using Velp instrument and according to the Standard Method for the Examination of Water and Wastewater, 1992 using the closed reflux, titrimetric method.

Samples have been taken from the three ponds and transported separately, then treated separately or mixed together to simulate the real treatment conditions. The mixing ratio was 1:1:2.4. The mixing ratio represents the ration of the flow rate from each pond. After settling the samples aeration has been applied for some samples for two hours to investigate the effect of coagulation on the organic matter removal efficiency.

Table 1 shows analysis for samples from the three ponds inlet and outlets without any treatment other. The samples have been analyzed by the City Council. The results show that bad treatment performance for all of the ponds may be due to the accumulation of the sludge within the ponds together with the absence of proper de-sludging that leads to frequent wash out of the sludge with the outlet of the pond. The wash out of the sludge may be the reason for increasing the dissolved solids concentration of the outlet samples than that of the inlet samples. The coagulants used in the study are alum, lime, ferrous sulfates, ferric chloride, mixture of alum and ferric chloride and mixture of alum and ferrous sulfates. Doses of the coagulant ranged from 50 to 250 ppm.

Table 1 Wastewater samples Analysis (source, 10th of Ramadan City Council)

Item	1st Pond Conc., ppm		2nd Pond Conc., ppm		3rd Pond Conc., ppm	
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
pH	7	6.8	6.9	7.2	9	7.5
T.D.S	415	772	1356	1104	1537	952
S.S	27	55	309	12	117	361
Settable S.S after 10 min., cm^3	1	0.6	4	0	10	0.4
Settable S.S after 30 min., cm^3	1.2	0.8	4	0.1	12	0.9
COD	1584	1936	1056	1264	2218	1528
BOD	248	213	285	180	383	585
Nitrates, NO_3	0.18	0.18	0.63	0.27	0.45	0.45
Cyanide	< 0.01	< 0.01	< 0.014	< 0.03	< 0.014	< 0.04
Sulfur, S^-	0.4	4.4	8.2	5.0	2.7	4.0
Sulfate, SO_4	0.28	0.7	0.4	0.67	2.4	0.08
Fluoride	0.5	0.5	0.4	0.5	0.6	0.5
Ammonia, NH_4	12.9	16.0	11.4	13.0	9.2	13.8
Phenol	0.1	0.7	0.7	2.1	0.4	1.2
Oil and Grease	5.8	10.3	6.0	10.0	8.8	10.6
Copper	< 0.01	0.08	0.04	< 0.01	< 0.01	< 0.01
Zink	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cadmium	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Lead	0.06	0.05	0.03	0.02	0.03	0.03
Chrome	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Nickel	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

RESULTS AND DISCUSSIONS

Coagulation and Precipitation

Average raw samples transmittance was 48% with minimum value of 42%, and maximum value of 50%. Figures (1-6) show different doses of coagulants verses the measured transmittance after precipitation for samples from the third industrial wastewater lagoon influent.

Figure (1) as present the transmittance for the samples treated with alum, shows that the best transmittance's 96%, took place at dose 250 ppm. The trend of the measurement shows more stable reading from dose of about 100 ppm than that of the low doses. For the Lime set of experiments, Figure (2) shows that the best transmittance, 80%, took place at dose of 200 ppm. The trend of the transmittance declines after the 200 ppm dose by about 3.6% at dose 250 ppm. Figure (3) as present the transmittance for the samples treated with ferrous sulfates, shows that the best transmittance, 94%, took place at dose 100 ppm. The trend of the transmittance declines after the 100 ppm dose by about 37% at dose 250 ppm may be due to the excess of the dose that makes the particles charge positive and form a repulsive force between the particles. Figure (4) as present the transmittance for the samples treated with ferric chloride, shows that the best transmittance, 97%, took place at dose 250 ppm. The trend of the measurement shows increases of the transmittance as the dose increase. The next two sets or results show the effect of using a mixture of two coagulants of the same dose.

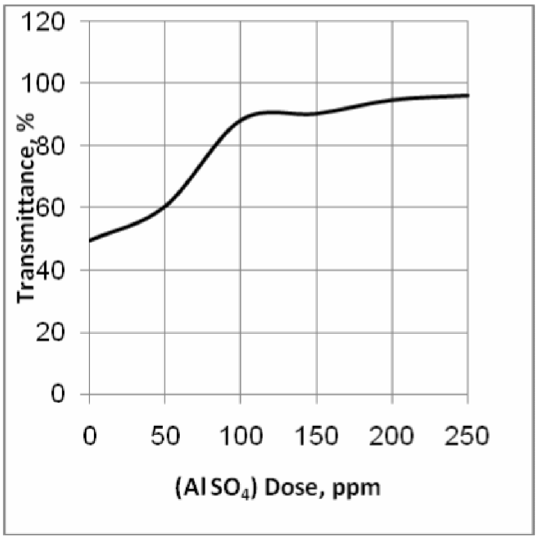

Figure 1 Alum Coagulate Transmittance

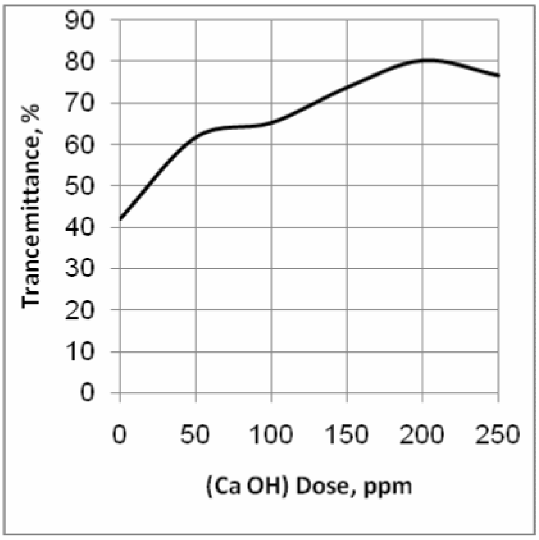

Figure 2 Lime Coagulate Transmittance

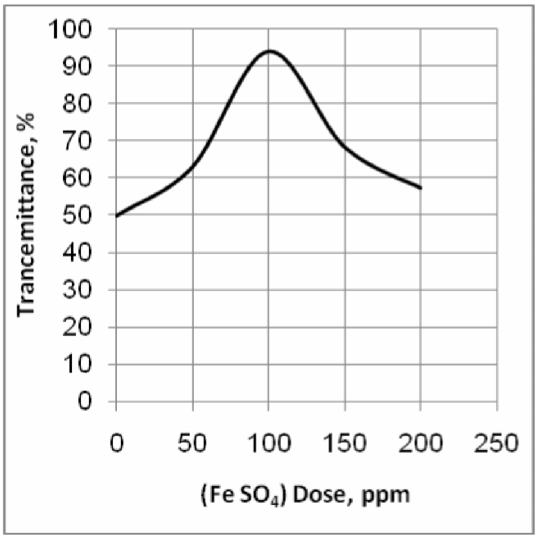

Figure 3 Fe SO_4 Coagulate Transmittance

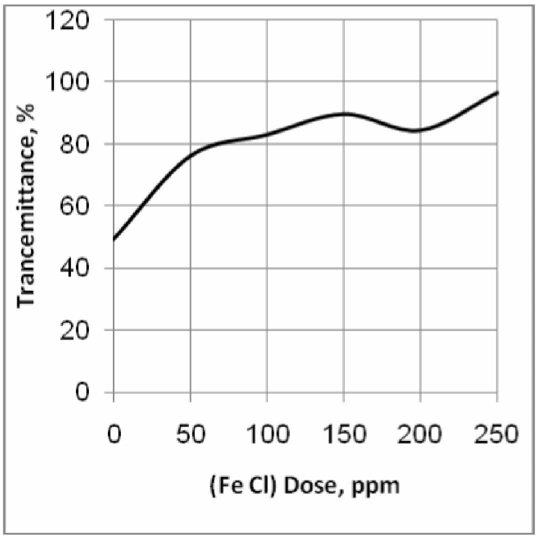

Figure 4 Fe Cl Coagulate Transmittance

Figure (5) shows the results of using a mixture of alum and ferric chloride with doses from 50 ppm (25+25) to 250 ppm. The peak transmittance reached 100% at doses 200 and 250. The trend is linear from dose 50 to 200 ppm, then it was stable at the 100% transmittance. Finally, the use of two coagulants of alum and ferrus sulfates, Figure (6) shows that the highest transmittance (84%) took place at dose 150 ppm. Nearly the transmittances were stable for all doses with average value of about 82%.

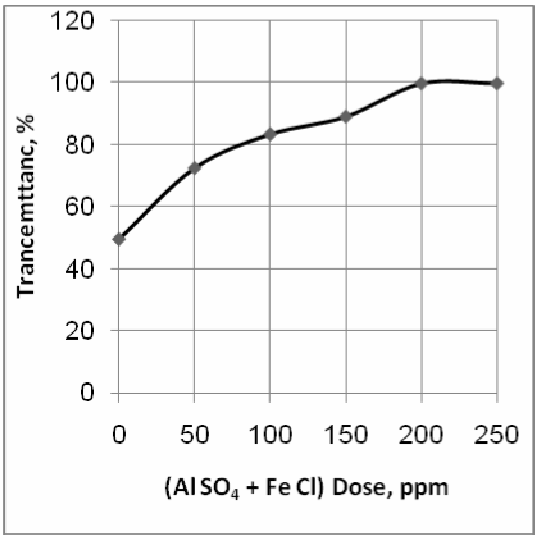

Figure 5 Al SO_4 + Fe Cle Coagulate Transmittance

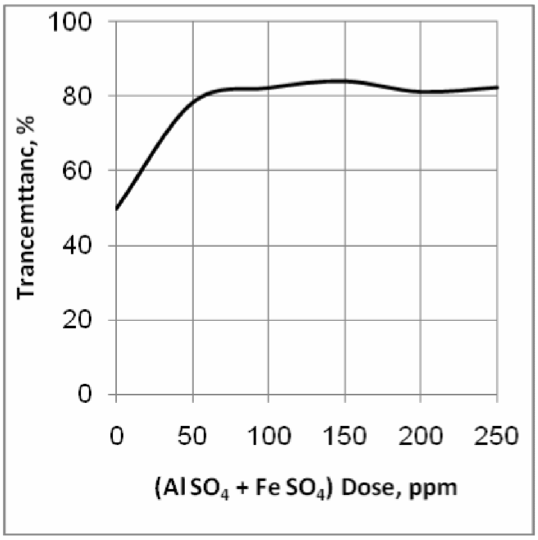

Figure 6 Al SO_4 + Fe SO_4 Coagulate Transmittance

The best results were obtained using a combination of the alum and the ferric chloride that the transmittance reached 100% at dose 200 ppm (100 ppm of alum + 100 ppm of ferric chloride). However, the high dose of the chemical used may limit the application of the chemical precipitation for economical issues.

Aeration

The second set of experiments investigated the organic removal of samples from the third industrial wastewater lagoon inlet that was aerated for two hours after chemically coagulation and precipitation using alum. Figure (7) shows the COD of the samples without adding coagulant and the COD of the coagulated and settled samples with alum at dose of 100, 150, 200, and 250 ppm.

The COD of the coagulated samples ranged from 390 to 430 ppm, while the COD of the reference sample was about 700 ppm. Increasing the dose of the alum from 100 ppm to 250 ppm does not reveled better COD removal. The average COD increase in removal ratio due to the use of alum a coagulant is about 40%. However, the COD of the samples is still at high concentration. However, the activated sludge system includes recalculated sludge and prolonged aeration time that will help improving the organic matter removal.

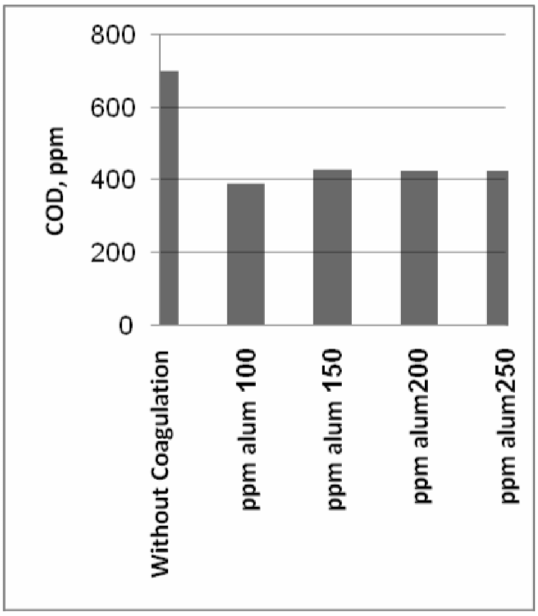

Figure 7 COD after 2 Hours of Aeration

CONCLUSIONS

Based upon the experiments results in the study and limited to the conditions determined a prior, the following observations and conclusions could be drawn:

- Using coagulation and sedimentation improve the removal of the colloidal suspended solids form the industrial wastewater.
- Alum and ferrous sulfate showed better turbidity removal than that of the lime and ferric chloride.
- A mixture of alum and ferric chloride removed all the colloidal suspended solids at dose of 200 ppm.
- Using the coagulation and precipitation improve the COD removal by about 40%.
- The relatively high coagulants dose and cost may limit the application of the study in the field and study for the treatment inside factories rather than the mixed wastewater is recommended.

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