The Combined Effect of Ferric Chloride and Cationic Poly-Electrolyte CPE on Coagulation of Grey Wastewater

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Abstract. The cationic polyelectrolyte is commonly adopted as a coagulant aid to reinforce the function of coagulant agent in industrial and municipal purposes; As a result, ferric chloride could be considered as the major chemical coagulant and Cationic Poly Electrolyte CPE as the coagulant aid. A set of examinations were implemented to minimize the amounts of both ferric chloride and CPE and to increase the removal efficiencies for the contaminants concentrations such as turbidity, total suspended solids (TSS), total dissolved solids (TDS) and chemical oxygen demand (COD) originated in grey wastewater so as to reuse these water for irrigation purposes. The combination of ferric chloride and cationic polyelectrolyte was found to improve the results for pollutants removal efficiency (Turbidity, TSS, TDS, and COD), by (97.5%, 91%, 88% 75%) respectively. The predicted results from artificial neural network (ANN) approach versus that observed from the experimental study for COD, TDS, TSS and turbidity removal showed an acceptable agreement for all models. All the parameters had a value of \(R^2\) of (0.9972, 0.9993, 0.9992, 0.9985) respectively

Keyword: Coagulation, ferric chloride, coagulant aid, wastewater treatment

1. Introduction
Gray water, wastewater produced by house actions such as cleansing, rinsing, bathing and laundering expelling toilet waste [1]. Grey water is commonly less polluted than toilet water; it has less parasites and about 90% lesser nitrogen than toilet water [2]. The greywater reclaiming increased in the recent years, principally as available clarification to water scarcity in developing countries, and it is fulfilling a fast growth on general level nowadays [3]. By recycling greywaters the drinking water demand per capita and the amount of the generated and drained wastewater can be remarkably decreased. A critical issue in greywater reusing is the water quality standardizations. Water analysis offers several of appropriate and effective estimating instruments, which assist the specific planning of the pollutants. The seniority of the applicable studies examines the organic, nutriment and biological pollution in greywaters. [4]. The activity of coagulation has been known as a pre-process that achieves filtration. In this process, coagulants cause rawer particles in water and these particles are separated from the water by sedimentation or filtration processes. Primarily, metal salts like alum, ferric sulphate, ferrous sulphate, ferric chloride, and anionic cationic and non-ion organic polymers are called coagulants. Coagulants and/or flocculants are necessary to reduce these particles, by discontinuing their stability. Agglomeration, generated in this manner, can be removed from the polluted waters [5]. In most conditions aluminium and ferric compounds are adopted to neutralize charge. Aluminium sulphate has...
been adopted as a major chemical usage for water treatment operation for more than 300 years. Because of its cheapest price as compared with other materials. However, Ferric chloride considers superior appropriate for its usage on water treatment operation in many countries such as Australia, United States of America and Canada. Because it displays an efficient solution for particles destabilization, reduction of total suspended solids and total dissolved solids, induction of flocculation and also improvement of filtration. In many cases the process cationic polyelectrolytes are more promising flocculants to undermine the polluting particles that are negatively charged. The electrostatic reaction provides strong adsorption that neutralizes the surface of the particles leading to the reflection of the charge. Furthermore, the flocculation may occur due to the reduction of the particle surface charge and the low electrical repulsion between them. Many studies conducted on polyelectrolyte of maxim charge density are simply effective as, in a given dose; they have a good ability to make more charge to particle shell. [6]. The purpose of this research is to minimize the contaminants concentrations of the grey wastewater using a combination solution (ferric chloride) and polymers (coagulant aid), so as to get higher removal efficiencies for several pollutants such as turbidity, total suspended solids, total dissolved solids and chemical oxygen demand (COD). So that the treated water can be used for re-using and re-cycling purposes. And also prediction the removal efficiencies of these pollutants by apply ANN technique.

2. Experimental Works

2.1. Formulation of synthetic wastewater
The composition and characteristics of used wastewater are shown in table 1 and table 2.

| Table 1. Composition of Synthetic Greywater [7] |
|-----------------------------------------------|
| Compound                           | Concentration (mg/l) |
| Glucose                            | 300                  |
| Sodium acetate trihydrate         | 400                  |
| Ammonium chloride                 | 225                  |
| Disodium hydrogen phosphate       | 150                  |
| Potassium dihydrogen phosphate   | 75                   |
| Magnesium sulphate                | 50                   |
| Cow dung                          | 225                  |

| Table 2. Characteristics of Synthetic Greywater. |
|-----------------------------------------------|
| Parameter        | Unit | Value |
| pH               | -    | 6.5   |
| Turbidity        | NTU  | 60    |
| TSS              | mg/l | 350   |
| TDS              | mg/l | 800   |
| COD              | mg/l | 300   |

2.2. Chemicals and Coagulants
The coagulants and chemicals used to improvement the removal efficiency, included FeCl3, and cationic polymer. Stock solution of ferric chloride was formulated by adding 10gm of FeCl3 to 1000 ml of distilled water at 60˚c to make a homogenous solution of ferric chloride solution concentration of 1%. Thus, each 1 ml/l of stock solution included 10 mg/l of FeCl3. The polyelectrolyte solution was formulated by dissolving 1.0gm of the synthetic polymer into 10 ml of alcohol to be more abandoned into the water, then diluted into tab water at 1000 ml to give solution of concentration 0.1%. Thus, 1 ml/l of solution is corresponding to 1 mg/l polymer. The most preferred dosage of the singular coagulant
or combination of more than one chemical was determined by Jar test, the cationic polyelectrolyte used commercially known as (Mangafloc LT 225) (polyalkenyimine) multipurpose polymer with a molecular range (10000-500000).

2.3. Best Dose of Coagulant and Polyelectrolyte
The prime method adopted to calculate the best and optimum coagulant dosage is jar test method. The one litter cylinder jars were filled with wastewater sample. In each jar, a divergent infusion concentration is adjusted with several dosages 10, 20, 30, and 40 mg / l. During the experiment, the jars submitted to a fast mixing velocity 120 revolutions per minute for 2 min so as to disperse the coagulant in all solution and then a gentle mixing velocity 2 revolutions per minute for 30 min for so as to get flocs generation. Then after that, the mixers are switched off and taking a period of 30 minutes for flocs sedimentation process. After the sedimentation period has finished, samples were taken from a distance 3-4 cm under the water surface of each beaker by a medical syringe. The samples were tested for determination the removal of turbidity, TDS, TSS and COD. The best dose was determined for ferric chloride, polyelectrolyte, and them combination.

2.4. Artificial Neural Network Approach (ANN)
The artificial neural network (ANN) is computing system that considered nonlinear statistical data modeling tools. This system designed to solve the most complex problems and simulate the way as the human brain processes and analyzes the information. ANN is used to predict the physical, chemical, and biological parameters in this study by interpolating and extrapolating the data. ANN is a mathematical model can be described by neurons. Each neuron acquires an input information, which is the biased sum total of the outputs of previous neurons. The neuron behaves on this input by mechanism of an activation function and a bias utility. ANN structure contains at least three components, the first one called as input layer (ferric chloride dosage, CPE dosage, initial COD, initial TSS, initial TDS and initial turbidity), the second component is the hidden layer and the third part noun as an output layer (COD, TSS, TDS and turbidity removals) as shown in figure 1. ANN structure may have two or more hidden layers; each hidden layer has a learning value to maximum the transforming of input layer. In this study, the sigmoid activation function was adopted to model the experimental data, weights were measured using Quick Propagation Algorithm (QP) and the connection between neurons of each layer to solve and transfer the experimental data using Multilayer Normal Feed Forward (MNFF).

**Figure 1.** ANN structure for the model.
3. Results and Discussion

3.1. Using Ferric Chloride only

Figure 2 to figure 5 show the effect of various ferric chloride doses, on wastewater quality parameters like (Turbidity, TSS, TDS and COD) with initial values of (60 NTU, 350 mg/l, 800 mg/l and 300 mg/l) respectively. From figure (2) it appears that ferric chloride dose of 25 – 35 mg/l gave the maximum turbidity removal efficiency (92%) while the maximum TSS reduction was 88% for the same range of dosage (25 – 35 mg/l) as shown in figure 3. The effect of ferric chloride effect on TDS removal efficiency could be shown from figure 4), the maximum removal was 87% was done using coagulant dose of 20 mg/l. Figure (5) illustrated the COD removal efficiency of using ferric chloride, the removal was 66% using a dosage of 30 mg/l.

![Figure 2. Effect of ferric chloride only on turbidity removal.](image)

![Figure 3. Effect of ferric chloride only on TSS removal.](image)
Combination Effect of Ferric Chloride and CPE

The cationic polyelectrolyte is commonly adopted as a coagulant aid to reinforce the function of coagulant agent in industrial and municipal purposes; As a result, ferric chloride will be considered as the major chemical coagulant and CPE as the coagulant aid. In this manner, a set of experiments were carried out on the treatment of grey wastewater of relatively low turbidity by ferric chloride at dose range of 10 to 40 mg/l and adding CPE in the range of 1 mg/l to 3 mg/l by using an increment of 0.5 mg/l) to support the flocs formation as well as the sedimentation behavior. The adoption of the little turbidity scale for the synthetic wastewater is depended on the fact that reutilizing practices concern treated wastewater close to hand for discharging. The effect of different ferric chloride dosages on the removal efficiency of turbidity, total suspended solids, total dissolved solids, electrical conductivity and chemical
oxygen demand of the grey wastewater at many levels of CPE (1, 1.5, 2.0, 2.5, and 3 mg/l). The initial pollutants concentrations for (Turbidity 60 NTU), (TSS 350 mg/l), (TDS 800 mg/l) and (COD, 300 mg/l). These results are typically plotted in figures 6 to 10.

3.2.1 Turbidity

As shown previously in figure 2 the total removal efficiency was 92% and achieved by using 30 mg/l as ferric chloride coagulant without any addition of coagulant aid. Figure 6 shows that the total removal efficiency increased to 97.5% and decreasing ferric chloride dosage to 20 mg/l when a combination of 2 mg/l of CPE is used.

3.2.2 Total Suspended Solids (TSS)

As shown previously in figure 3 the total removal efficiency was 88% and achieved by using 30 mg/l as ferric chloride coagulant without any addition of coagulant aid. Figure 7 shows that the total removal efficiency increased to 91.14% and decreasing ferric chloride dosage to 20 mg/l when a combination of 2 mg/l of CPE is used.

3.2.3 Total Dissolved Solids (TDS)

As shown previously in figure 4 the total removal efficiency was 87% and achieved by using 20 mg/l as ferric chloride coagulant without any addition of coagulant aid. Figure 8 shows that the total removal efficiency increased to 88% when a combination of 1 mg/l of CPE is used.

3.2.4 Chemical Oxygen Demand (COD)

The combinations of coagulant and coagulant aid have an important impact on the COD removal efficiency as illustrated in figure 10 when using CPE by dose of 2.5 mg/l, the COD removal efficiency increased to 75% using ferric chloride of 20 mg/l while the COD removal was 65% using 30mg/l ferric chloride without additional of CPE. This combination of CPE had a clear effect in decreasing the dosage of coagulant and increasing removal efficiency. Similar results had been got by [8] at their study of the effect of several coagulant aids (polymers) on the COD removal efficiency. From the overall results it can be seen that the arrangement of CPE with ferric chloride leads to minimize the amounts of both ferric and CPE and increasing the removal efficiencies for the pollutants in grey wastewater. The reduction in quantities of ferric chloride and CPE is essential for economical purposes and operation conditions, addition to reducing the sludge, the disposal complications and diminishes filter blocking problems during filtration process; reduction of ferric chloride dosages means constrained increment of pH values.
**Figure 6.** Effect of combination addition of ferric chloride and CPE on turbidity removal.

**Figure 7.** Effect of combination addition of ferric chloride and CPE on the TSS removal.

**Figure 8.** Effect of combination addition of ferric chloride and CPE on the TDS removal.
3.2.5 ANN Model Output

The ANN model accuracy and also time spend to reach the best solution, that gives the best coincidence with the observed data for the studied phenomenon, depending on number of neurons in the hidden layer. Hence, many numbers of hidden layers were examined and the number of layers that satisfied RMSE less than 0.05 were adopted. Figures 11 to 14 show the predicted results from ANN approach versus that observed from the experimental study for COD, TDS, TSS and turbidity removal respectively. The results showed an acceptable agreement for all models. All the parameters had a value of R² of (0.9972, 0.9993, 0.9992, 0.9985) respectively.
Figure 11. Predicted- Observed fitted line of ANN Results for COD.

Figure 12. Predicted- Observed fitted line of ANN Results for TDS.

Figure 13. Predicted- Observed fitted line of ANN Results for TSS.
4. Conclusion
Pollutants removal efficiency (Turbidity, TSS, TDS, and COD), by (92%, 88%, 87% 66%) respectively could be obtained by using ferric chloride solution of concentration 20-35 mg/L only without addition of cationic polyelectrolyte. The combination of ferric chloride and cationic polyelectrolyte was found to improve the results for pollutants removal efficiency (Turbidity, TSS, TDS, and COD), by (97.5%, 91%, 88% 75%) respectively addition to decrease the dosage of the used coagulant. The reduction in quantities of ferric chloride and CPE is essential for economical purposes and operation conditions, addition to reducing the sludge, the disposal complications and diminishes filter blocking problems during filtration process; reduction of ferric chloride dosages means constrained increment of pH values. Finally, the predicted results from artificial neural network (ANN) approach versus that observed from the experimental study for COD, TDS, TSS and turbidity removal showed an acceptable agreement for all models. All the parameters had a value of R2 of (0.9972, 0.9993, 0.9992, 0.9985) respectively.

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