Ain Shams University, Faculty of Engineering

Ain Shams Journal of Civil Engineering
(ASJCE)

Upgrading of Wastewater Treatment Plant by the Use of Coagulation Flocculation Process

Hanan A. Fouad[1]

[1] Civil Engineering Department, Faculty of Engineering, Banha University.
Egypt. E-mail: h_a_fouad@yahoo.com

ARTICLE HISTORY

Received: / / 2009
Accepted: / / 2009

ABSTRACT

This study investigated the effect of coagulation/flocculation treatment process on upgrading wastewater treatment plant. A comparison between two different coagulants (alum – ferric chloride) with different dosage and pH values were applied to the coagulation processes. The experiments were performed in a conventional jar-test apparatus in El Berka wastewater treatment plant in El Sallam district, Cairo, Egypt. The results reveal that pH values (7–8), enhance removal efficiency of the COD, TSS and total phosphorous (TP). Percentage removal of 25.7%, 52.6% and 16.7% of COD, TSS and TP, of the blank sample while the removal efficiency increased to be 55.2%, 84.4% and 64% of COD, TSS and TP, respectively, by the addition of 80 mg/L alum and 66.1%, 91.6% and 89.5% removal of COD, TSS and TP, respectively, were achieved with the addition of 100 mg/L ferric chloride to the wastewater samples. The optimum pH value for alum was 7 and 8 for ferric chloride.

Keywords

wastewater treatment, coagulant dose, pH, coagulation

Introduction

Physical-chemical treatment of wastewater originated in the 18th century, and was widely relied upon in the late 19th and early 20th centuries as part of sanitation schemes for municipal areas. In recent years however, chemically enhanced primary treatment, a variation of the early process that relies on considerably lower dosages of chemicals, has found applicability in large-scale treatment solutions in which high seasonal hydraulic loading variations are experienced; where there is limited space availability; and where the characteristics of the receiving stream require treatment levels higher than primary, but not quite as stringent as secondary. Using coagulant gives the ability to remove phosphorus, a macronutrient associated with eutrophication problems in some receiving water bodies. Also, incorporating chemical addition to primary clarifiers is being used to increase existing treatment capacities as well as for reducing the influent loads to subsequent biological treatment stages in facilities required to meet more stringent standards (1). Aluminium and iron salts are widely used as coagulants wastewater treatment. Coagulation can be summarized in neutralization of negatively charged colloids by cationic hydrolysis products and incorporation of impurities in an amorphous hydroxide precipitate so-called sweep flocculation. The relative importance of these mechanisms depends on factors such as pH and coagulant dosage (2).

On the other words coagulation is the process of decreasing or neutralizing the electric charge on suspended particles or zeta potential. Like electric charges on small particles in water cause them to naturally repel each other and hold the small, colloidal particles apart, keeping them in suspension. The coagulation/flocculation process neutralizes or reduces the negative charge on these particles, which then allows the van der Waals force of attraction to encourage initial aggregation of colloidal and fine suspended materials to form microfloc. Flocculation is the process of bringing together the microfloc particles to form large agglomerations by physically mixing or through the binding action of flocculants. In addition, both aluminum and iron salts can also be used for the chemical precipitation of phosphorus. The basic reactions involved are:

$Al^{+3}+PO4^{-3} \Leftrightarrow AlPO4$

$Fe^{+3}+PO4^{-3} \Leftrightarrow FePO4$

The above equation is the simplest forms of the reaction (3). Due to the many other competing reactions, the effects of alkalinity, pH, trace elements, and other compounds in the wastewater, the actual chemical dosage required to remove a given quantity of phosphorus is usually established on the basis of bench-scale test or sometimes pilot-scale tests (4). The chemicals themselves make only a slight contribution to the total sludge production. The greatest portion of the increase of sludge production is due to the increased solids removal in the settling tank. And that is precisely CEPT's goal. CEPT treatment does not preclude secondary or tertiary treatment. It makes any subsequent treatment smaller and less costly due to the increased efficiency. CEPT is a relatively

simple technology providing a low-cost and effective treatment, which is easily implemented over existing infrastructure (5). The present investigation aims optimization of the coagulant dosages and pH to achieve highest removal of COD, TSS and TP.

Material and Methods

The main objective of this study is to evaluate the effect of coagulants dose and pH on the coagulation process of the wastewater. The wastewater used in these experiments was obtained from the effluent channel of the grit removal chamber of El-Berka wastewater treatment plant. The physical and chemical properties of the wastewater are presented in table 1.

Table 1: The physical and chemical properties of the wastewater

Measuring parameters	Description
Total solids (mg/l)	880
Total suspended solids (mg/l)	190
COD (mg/l)	522
TP (mg P/l)	4.2
Temperature	24
pH	7.12

The experiments were performed in a conventional jar-test apparatus, equipped with six beakers of 1 L volume at room temperature. The experimental process consisted of three subsequent stages: the initial rapid mixing stage took place for 1 min at 200 rpm, followed by a slow mixing stage for 20 min at 30 rpm. Stirring was then discontinued and the sludge was left to settle. After the settling period, the supernatant was withdrawn from a point located about 2 cm below the top of the liquid level of the beaker to determine the COD, TSS, and TP by using standard methods (6). The experiments conducted through two stages.

Stage 1:

Phase 1: different doses of Alum Al2(SO4) ranged from 20 mg/l to 100 mg/l were added to the wastewater samples to determine the optimum coagulant dose which gives the best removal efficiency of COD, TSS, and TP.

Phase 2: different doses of different doses of ferric chloride ranged from 20 mg/l to 100 mg/l were added to the wastewater samples to determine the optimum coagulant dose which gives the best removal efficiency of COD, TSS, and TP.

Stage 2: The pH value of the wastewater samples was adjusted to a pH 5 – 9, respectively, by addition of appropriate amounts of HCl to decrease pH to 6 and 5 or NaOH to rise the pH to 8 and 9 before adding the optimum dose of alum and ferric chloride to evaluate the effect of pH on the coagulation process. Figure 1 and figure 2 show the photos of the jar test experiments and settling

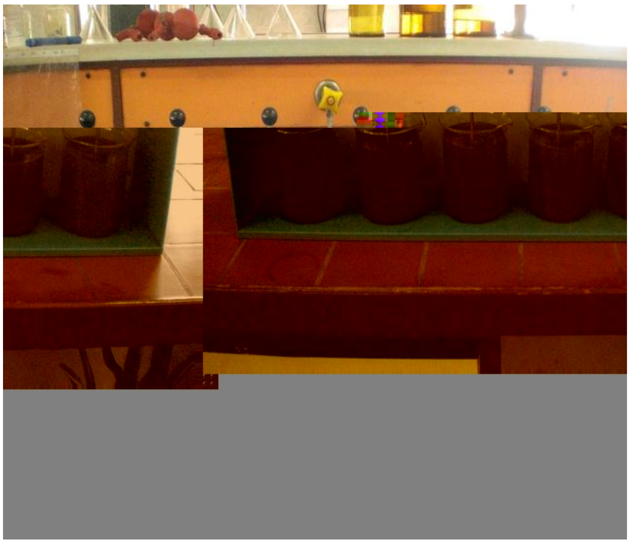

Figure 1 The photos of the jar test experiments

Figure 2 The photos of the settling

Results and Discussion

Stage 1: In this stage alum and ferric chloride were added to the wastewater samples with doses ranged from 20 to 100 mg/l. The removal efficiency of the COD were 41%, 43.1%, 44.83%, 55.17% and 38.5% for alum doses 20, 40, 60, 80 and 100 mg/l respectively. On the other hand the removal efficiency of the COD were 33.33%, 59.77%, 64.37%, 65.1% and 66.1% for ferric chloride doses 20, 40, 60, 80 and 100 mg/l respectively and 25.67% for the blank wastewater sample. Figure 3 illustrate the removal efficiency of the COD for this stage. Thus it can be observed that the optimum dose of the alum was 80 mg/l and 100 mg/l for ferric chloride.

Figure 4 illustrates that the optimum removal efficiency of TSS is 84.4% at alum dose 80 mg/l and 91.58 % at ferric chloride dose 100 mg/l while the removal efficiency of the blank sample was 52.6%. The removal efficiency of ferric chloride is more than the removal efficiency of the alum at the same dosage.

Figure 5 shows a comparison of the effectiveness of alum and ferric chloride in removing total phosphorous from the wastewater samples. The removal efficiency of the blank sample was 16.7% while at concentration 100 mg/l of ferric chloride, total phosphorous removal efficiency increased to be 91.58% and 64% at concentration 80 mg/l of alum. It is may be attributed to the molecular weights of these compounds. These results indicates that the ferric chloride should be more effective on a weight basis. Similarly Kyung (7) was found that addition of alum in the aeration tank had a positive effect on phosphorus removal along with minimization of membrane fouling.

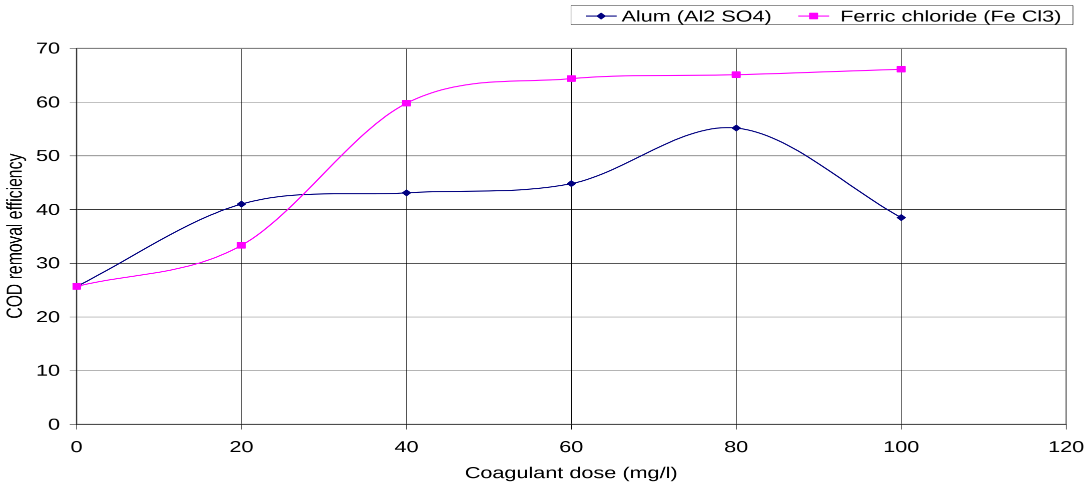

Figure 3 The relationship between the COD removal efficiency and coagulant dose

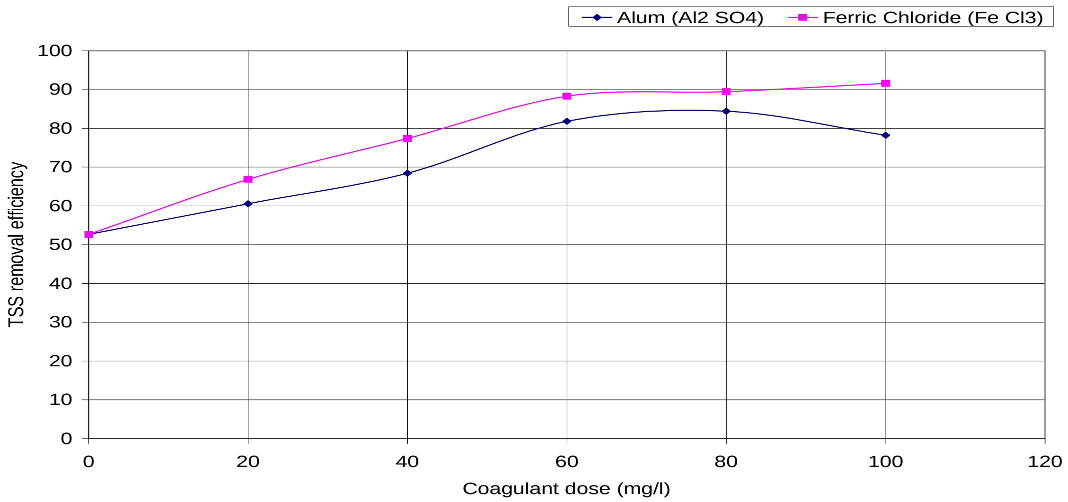

Figure 4 The relationship between the TSS removal efficiency and coagulant dose

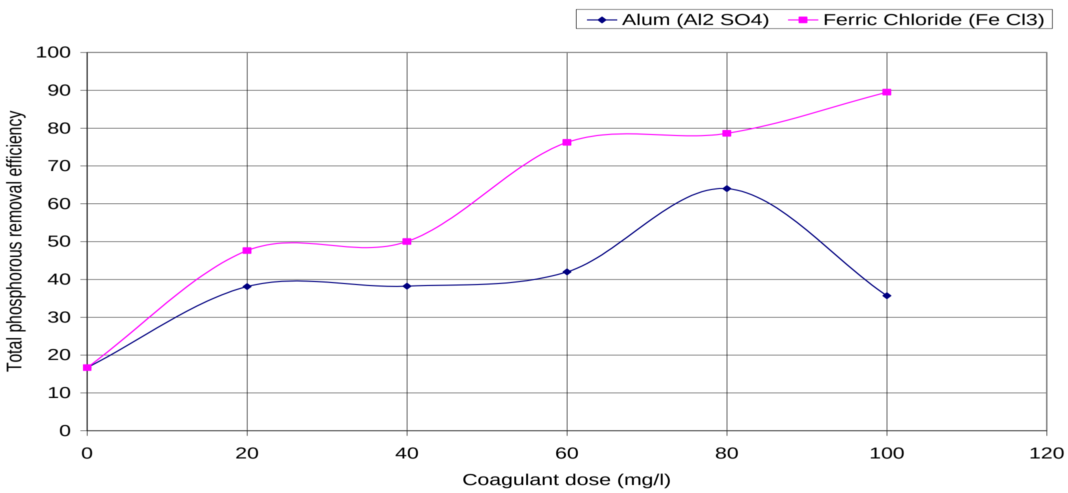

Figure 5 The relationship between the TP removal efficiency and coagulant

Stage 2: In this stage pH value of the wastewater samples was adjusted to a pH 5 – 9 before adding the optimum dose of alum which is 80 mg/l and 100 mg/l ferric chloride to evaluate the effect of pH on the coagulation.

Figure 6 shows that the best pH value for alum which gives the best removal efficiency of COD, TSS and TP is 7. On the other hand the pH value which gives the best removal efficiency of COD, TSS and TP is 8 for ferric chloride as shown in figure 7. The removal efficiency decreases as the pH increases above 8. It is may be attributed to the production of negatively charged organic contaminants on which adsorption will be electro statically hindered (8). The increase in TSS removal efficiency at higher pH was due to destabilization of the flocks influenced the removal differing from COD removal. This study evidenced once again that coagulation process can assure the limits of COD, TSS and TP for municipal wastewater treatment plants providing high removal efficiency using relatively low level of aluminum sulphate or ferric chloride (9).

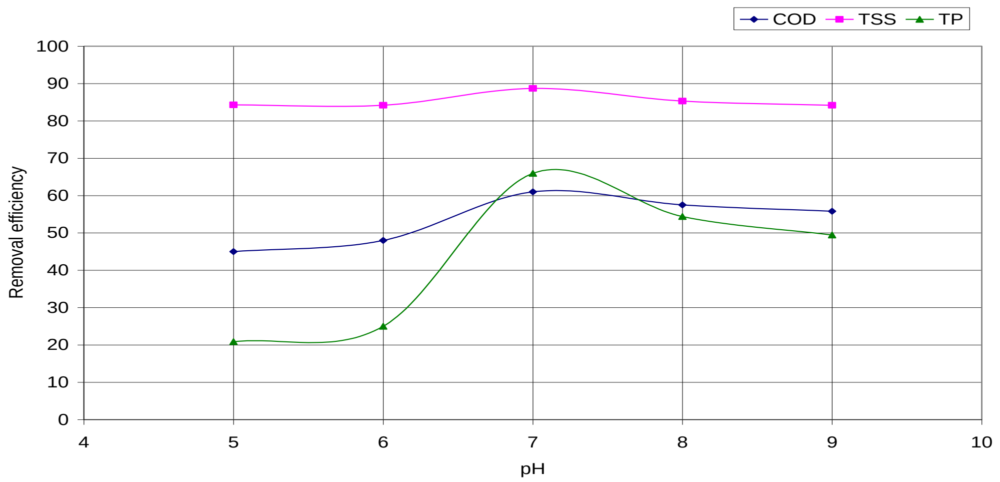

Figure 6 The relationship between pH and COD, TSS and TP removal efficiency for 80 mg/l alum

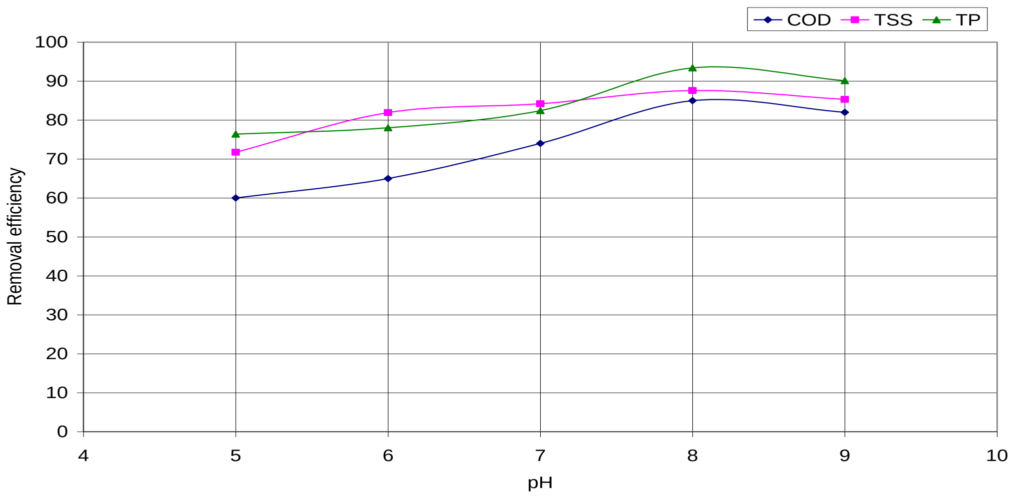

Figure 7 The relationship between pH and COD, TSS and TP removal efficiency for 100 mg/l ferric chloride

The solution pH played an important role in the phosphorous removal. Higher pH can cause higher phosphorous removal percentage. Its removal decreased in the presence of the competitive matters, such as Cl^-, CO_3^{2-}, SO_4^{2-} and humic acid (10).

Conclusion

Based on the experimental program executed in this research, and limited on both the tested materials and the testing procedures employed, the following conclusions had been reached:

1- Using coagulants in wastewater treatment increase the COD, TSS and TP removal efficiency.

2- The optimum dose of alum was 80 mg/l which gives the removal efficiency 55.2%, 84.4% and 64% of COD, TSS and TP, respectively. On the other hand the removal efficiency of COD, TSS and TP for the blank sample was 25.67%, 52.6% and 16.67%.

3- The optimum dose of ferric chloride was 100 gm/l which gives the removal efficiency 66.1%, 91.6% and 89.5% of COD, TSS and TP respectively.

4- The removal efficiency of TSS decreases on the addition of alum above 80 mg/l, this was as a result of re-suspension of solids at this concentration. Also, the high concentration of alum can confer positive charges on the particles surface (a positive zeta potential), thus re-dispersing the particles.

5- The optimum pH value for alum was 7 which gives the removal efficiency 61%, 88.7% and 67% of COD, TSS and TP respectively.

6- The optimum pH value for ferric chloride was 8 which gives the removal efficiency 85%, 87.6% and 93.4% of COD, TSS and TP respectively.

Acknowledgment

I would like to thank Dr. Shafeka the head of El Berka wastewater treatment plant's laboratory for her help in the experimental measurements.

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Hanan A. Fouad


Dr. Hanan Ahmed Fouad lecturer of sanitary and environmental engineering at faculty of engineering Banha university.

ملخص البحث

تهتم هذه الدراسة بتأثير المواد المروية على رفع كفاءة محطات معالجة مياه الصرف الصحي. فقد تمت المقارنة بين نوعين من المواد المروية (الشبة – كلوريد الحديديك) بجرعات مختلفة و كذلك تغيير الأس الهيدروجيني. تمت التجارب بواسطة (jar test)في معمل محطة البركة لمعالجة مياه الصرف الصحي. أظهرت نتائج التجارب تأثر كفاءة إزالة المحتوى الأوكسجينى الكيميائي و المواد العالقة و الفسفور بجرعات المواد المروبة المضافة و بالأس الهيدروجيني. فقد كانت كفاءة إزالة المحتوى الأوكسجينى الكيميائي و المواد العالقة و الفسفور هي 25.7%, 52.6%و١٦.٧% بينما عند إضافة الشبة ٨٠ ملجم/ل من الشبة إلى عينات مياه الصرف الصحي زادت كفاءة إزالة المحتوى الأوكسجينى الكيميائي و المواد العالقة و الفسفور إلى 55.2%, 84.4% و 64% بينما كانت كفاءة إزالة المحتوى الأوكسجينى الكيميائي و المواد العالقة و الفسفور هي 91.6%, 66.1% و 89.5% و ذلك عند إضافة ١٠٠ ملجم/ل من كلوريدات الحديدوز إلى عينات مياه الصرف الصحي. أفضل قيمة للأس الهيدروجيني كانت ٧ وذلك بالنسبة للشبة بينما كان ٨ لكلوريد الحديديك.