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Improvements to the dewaterability of ferric sludge produced from chemical treatment of wastewaters

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Abstract

Ferric chloride is an effective coagulant for the removal of suspended solids and appreciable amount of Chemical Oxygen Demand (COD) in sewage. Treatment of sewage by ferric chloride produced highly voluminous sludge which was resistant to dewatering process. Lime improves dewatering of ferric sludge by reducing specific resistance and increasing the compressibility characteristic of sludge depending on the dosage of conditioners. Flyash was also concluded as an effective conditioner due to a decrease in the specific resistance of sludge. On the other hand, addition of flyash decreased the compressibility coefficient of sludge.

1 Introduction

Wastewaters in recreational areas must be treated independently from a municipal treatment system if they are located too remote from urban areas to have a wastewater collection system that can be connected to a municipal wastewater treatment system.

The difficulty of maintaining an optimum environment for a biological treatment unit in recreational areas increases the importance of physical - chemical treatment for the indicated areas. However, the widespread usage of chemical substances in the physical-chemical treatment process increases the volume of sludge. The volume reduction of the sludge by the removal of excess water is required for the transportation of sludge conveniently to the ultimate disposal site.

In wastewater treatment facilities, handling of sludge is achieved by dewatering operation. Several chemical conditioners can be used to improve the sludge dewatering characteristics. However, lack of information and contradictions results in an inefficient operation of the dewatering systems.

The objectives of this research are to investigate the dewaterability characteristics of the sludges produced by ferric chloride as chemical coagulant for the treatment of sewage and to improve the dewaterability by using relatively cheap conditioners as lime and flyash.

2 Background

Effective design and control of the conditioning - dewatering step requires a procedure for quantifying sludge dewaterability. One of the method used for sludge dewaterability is the measurment of specific resistance. Specific resistance of a sludge is defined as the internal resistance of a cake to the passage of water. The mathematical expression for the specific resistance has been developed by Carman [1] who has taken Darcy's law [2] as a basis. The simplified form of the expression can be given as follows:

$$\frac{t}{v} = \frac{\mu w r v}{2PA^2} + \frac{R\mu}{PA} \tag{1}$$

where,

P = overall pressure of the system, N m^{-2}

R = resistance of filter medium, m^{-1}

A = filtration area, m^2

μ = absolute viscosity, N s m^{-2}

w = weight of dry cake solids per unit volume of filtrate, kg m^{-3}

r = specific resistance, m kg^{-1} (the high and low specific resistances indicate inferior and superior dewatering properties, respectively)

t= time of filtration, s

v= volume of filtrate, m^3

Coakley and Jones described a laboratory procedure for determining the specific resistance in the wastewater field [3]. By using Buchner funnel, it should be possible to measure the volume of filtrate v, under vacuum at various times t. Plotting these as t/v versus v, straight line is obtained. Based on the equation (1) the slope of this line b is equal to:

$$b = \frac{\mu\, rw}{2PA^2} \qquad (2)$$

Then specific resistance r, becomes,

$$r = \frac{2PA^2b}{\mu\, w} \qquad (3)$$

The variation of sludge specific resistance with applied pressure is related with compressibility of sludges. It is indicated by the compressibility coefficient which has been found according to the empirical equation as follows [2];

$$r = r_o p^s \qquad (4)$$

r, r_o = values of specific resistances calculated at different pressures, m kg^{-1}

p= ratio of two different pressures, dimensionless

s= coefficient of compressibility, dimensionless

3 Materials and Methods

Wastewater used in this study was obtained from Middle East Technical University treatment plant influent at Ankara. Merck type of powdered ferric chloride ($FeCl_3 6H_2O$) was used as a chemical coagulant for the treatment of wastewater. Jar test apparatus was used to produce ferric precipitated sludge. Sludge was produced by allowing the flocs settle down after the coagulation and flocculation process. Flyash and lime were used as chemical conditioners. The flyash used in this research was produced from the Lignite of Soma in Turkey. Merck type of lime was used as a conditioning agent. Specific resistance and compressibility of unconditioned and conditioned sludge were determined by using a Buchner Funnel apparatus.

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4 Results and Discussion

4.1 Chemical Treatment of Wastewater

Percent turbidity removal and Chemical Oxygen Demand (COD) remaining in the treated solutions with respect to the applied dosages of ferric chloride are given in Figures 1 and 2, respectively. Experiments were conducted for the ferric chloride dosages of 50 - 450 mg/l at an initial pH of 8.4. Turbidity removal was increased up to 91 % at 250 mg/l of ferric chloride. There was a slight change in the turbidity removal with the further addition of ferric chloride at the higher concentrations. At 350 mg/l, turbidity removal reached to its maximum value of 94 %. Turbidity removal did not change beyond this concentration. The results of the COD experiments indicated appreciable amount of COD removal by the ferric chloride treatment. Initial COD of wastewater was measured as 400 mg/l which was then, reduced to 120 mg/l at a ferric chloride dosage of 350 mg/l.

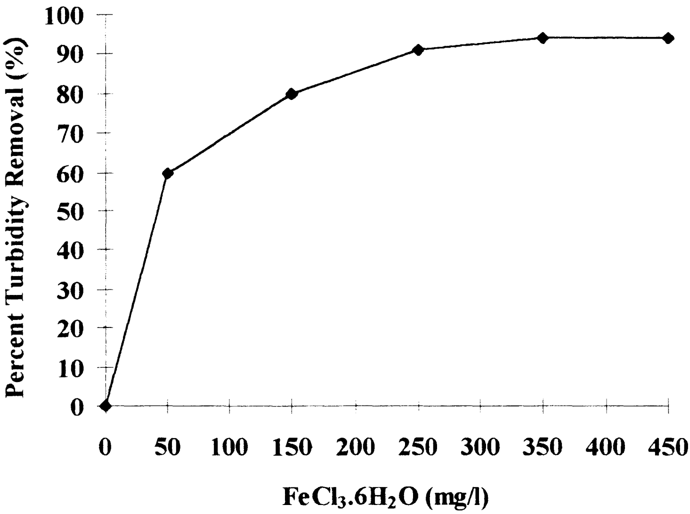

Figure 1. Percent Turbidity Removal versus Coagulant Dosage.

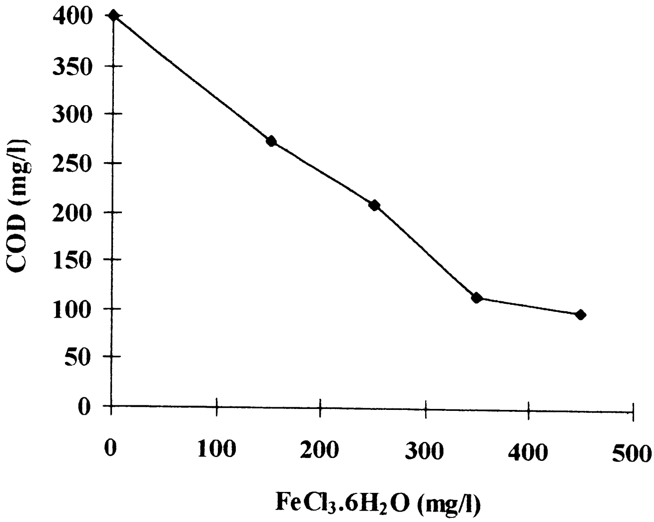

Figure 2. COD Concentration Remaining versus Coagulant Dosage

4.2 Sludge Characteristics

The volume of sludge generated by the application of ferric chloride was determined by measuring the sludge volume after 30 min. of settling time in a one liter of a graduated cylinder after the coagulation and flocculation. In Figure 3, volume of the settled sludge was given with respect to the ferric chloride dosages. An increase in the settled sludge volume was observed with an increase in coagulant concentration, since the sludge that was produced after the treatment included not only the undesirable constituents but also chemicals used in the treatment. It was observed from the figure that, above 250 mg/l, every 100 mg/l increase in concentration , increased the sludge volume by 5 ml /l. If water consumption at recreational area is assumed to be 200l/cap/day then, every 100 mg/l increase in coagulant concentration will bring an extra 1 l of sludge per capita. It should be noted that turbidity removal did not enhance to a greater extend after 250 mg/l. On the other hand, COD removal was increased almost 20 % by the increase of ferric chloride dosage from 250 mg/l to 350 mg/l. In recreational areas, the most effective dosage for the turbidity removal and the dosage which provides an appreciable amount of COD removal should be preferred to maintain highest water quality in the receiving water.

In the following phase of the study, ferric chloride dosage of 350 mg/l was used for sludge production. Treatment by ferric chloride at 350 mg/l produced voluminous sludge with a volume of 1000 to 1100 ml per gram of suspended solids. Hence, total mass produced in 35 ml of the settled sludge for the indicated dosage of ferric chloride(Figure 3) can be calculated as 0.035 to 0.032

gm. Then, dewatering characteristics of the produced sludge was investigated and its dewaterability was tried to be improved by using lime and flyash.

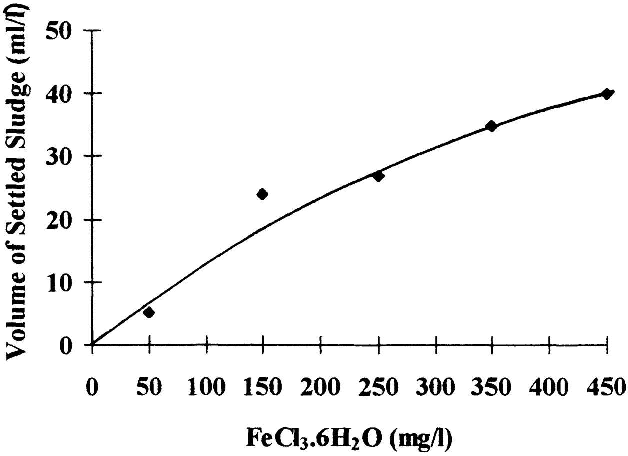

Figure 3. Volume of Settled Sludge Versus Coagulant Dosage.

4.3 Lime Conditioning of Sludge

Lime was added at various dosages to the sludge and specific resistances of the sludges were measured at 34, 51, 64 kNm^{-2} of vacuum. The results of the experiments are given in Figure 4 where the lime dosages are expressed as weight percents of the total sludge solids. At the all applied vacuums, specific resistance of sludge has decreased with the increase in lime dosages up to 3%. The role of calcium ions in lime conditioning of sludge has been suggested as the formation of Ca^{++} link between sludge particles in the alkaline medium. Further addition of lime above the dosage of 3 % increased the specific resistance of the sludge. This might be due to the formation of calcium carbonate precipitates by the addition of lime which was resulted in clogging of the pores in the sludge medium.

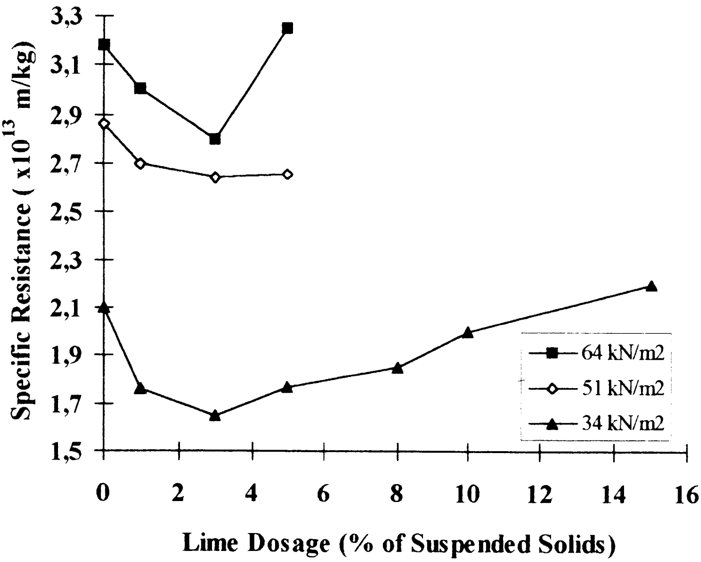

Figure 4. Specific Resistance versus Lime.

Compressibility coefficients with respect to lime dosages are given in Figure 5. The results indicate that lime increased the compressibility of the sludge by the addition of up to 3 % of lime dosage. Agglomeration of particles by the addition of lime also increased the compressibility characteristics of sludge. Further increase in lime dosage did not improve the compressibility of sludge significantly. Precipitates might form a structure in sludge which can not be compressed more at higher vacuums, and therefore, might prevent more water release.

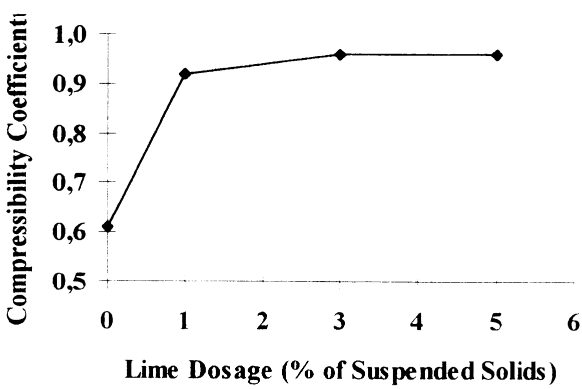

Figure 5. Compressibility Coefficient versus Lime.

4.4 Flyash Conditioning of Sludge

The effect of various dosages of flyash on the specific resistances of sludge at different applied vacuums is given in Figure 6. Flyash dosages were expressed as weight percents of the total sludge solids. For the vacuums tested at 51 and 64 kNm^{-2}, specific resistance of the sludge to filtration was decreased by the addition of flyash at all applied dosages. At 34 kNm^{-2}, specific resistance was decreased by the addition of flyash up to a dosage of 25 %. Previously, improvements was reported when flyash was used as a filter aid for the conditioning of activated sludge [4,5]. Based on the explanations given previously, improvement in vacuum filtration characteristics might be due to the formation of a cake with a more porous structure that prevented clogging by fine particles in the cake and filter medium. Moreover, increasing the concentration of flyash might give the filter cake a more rigid structure by providing avenues of flow for water to be withdrawn. On the other hand, at 34 kNm^{-2}, increases in the amount of flyash resulted in an increase in the specific resistances above 25 % of flyash dosage. As it was observed that (Figure 7) filtration time has also increased beyond 25 % of flyash dosage at 34 kNm^{-2} of vacuum. On the other hand, time of filtration has continuously decreased at all applied dosages at higher vacuums. Both figures 6 and 7 showed that after 25 % of the flyash dosage, the degree of dewatering was highly dependent on the applied vacuum. At higher vacuums (51 and 64 kNm^{-2}), water that was absorbed by the flyash was removed easier from the sludge as compared to the lower vacuum (34 kNm^{-2}).

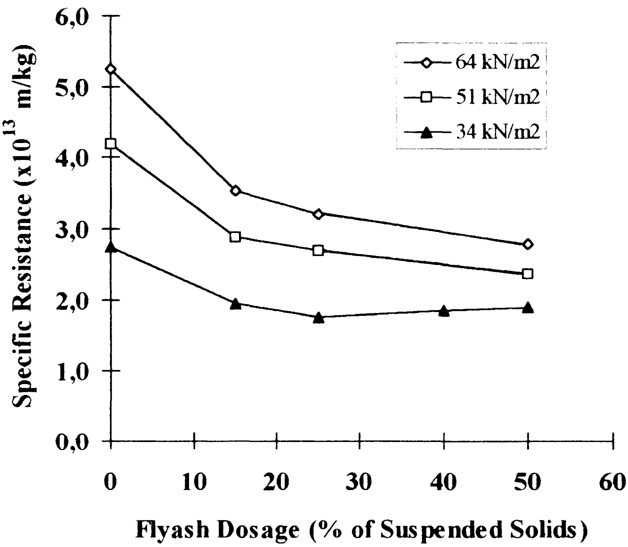

Figure 6. Specific Resistance versus Flyash Dosage.

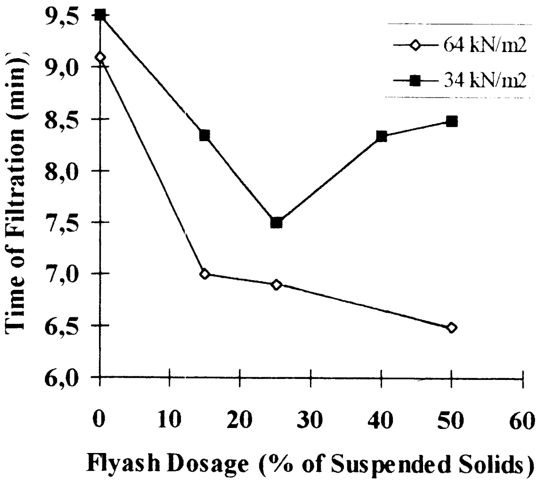

Figure 7. Time of Filtration versus Flyash Dosage.

Variations of the compressibility coefficient with respect to the flyash dosages are given in Figure 8. Compressibility coefficient was reduced from 1.6 to 0.68 at 50 % flyash dosage. It can be suggested that addition of flyash decreased the sludge compressibility due to the water absorption on flyash.

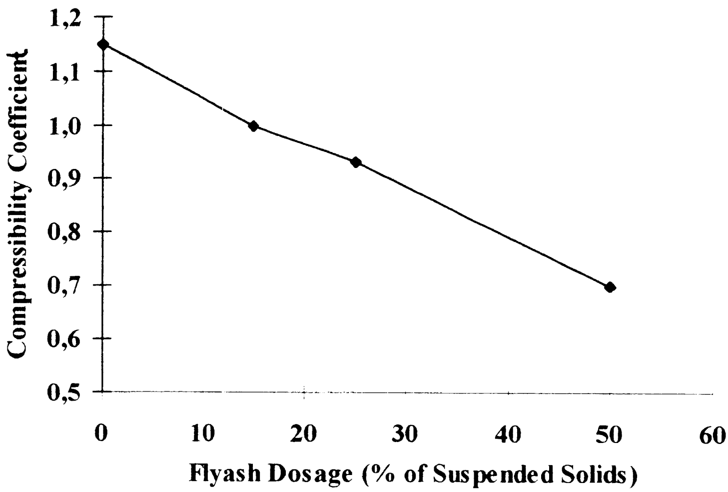

Figure 8. Compressibility Coefficient versus Flyash Dosage.

5 Conclusion

The precipitated sludge was voluminous and highly resistant to dewatering. Lime and Flyash improves dewatering of ferric sludge depending on the dewatering dosage.

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