

Sludge Density Prediction in a Wastewater Chemical Coagulation Process

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Received April 25, 2013; revised May 27, 2013; accepted June 30, 2013

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ABSTRACT

This paper reports an approach to estimate the sludge density in a physicochemical treatment of municipal wastewater, experiments considered 4 coagulants (aluminum sulfate SAl, iron sulfate SFe, aluminum polychloride PAX, iron polychloride PIX), and 2 flocculant products (cationic CP and anionic AP polymers). Experimental approach is based on running a set of jar tests at different coagulant concentrations. After the stirring and resting times took place, pH and conductivity were registered finding that SAl and SFe either with or without polymers are the coagulants producing the higher pH drop. Conductivity measures also establish two kind of data since higher conductivity (about $2000 \mu\text{S}\cdot\text{cm}^{-1}$) was observed for SAl, and PIX, PIX + CP, PIX + AP; otherwise a conductivity about $1300 \mu\text{S}\cdot\text{cm}^{-1}$ was observed for SAl + PC, SFe and PAX alone and with CP or AP. Settleable solids (SST) determined with an Imhoff cone were similar for sulfates and polychlorides, but dry sludge (DS) clearly set up two groups the one with higher sludge content corresponds to sulfates group. The quotient of DS divided by the SST provided an estimation of the apparent sludge density, in this way it was observed that higher densities were obtained for sludge from sulfates at lower coagulant concentrations; also sludge from SFe was heavier than the one from SAl. Otherwise, polychlorides produced a lighter sludge in respect to the one obtained with sulfates, and between them the PIX coagulant provided a heavier sludge than the PAX coagulant.

Keywords: Coagulant; Flocculant; Wastewater Treatment; Sludge Density

1. Introduction

Usually wastewater treatment plants (WWTP) are referred in three levels: primary, secondary and tertiary treatment. In Latin America, primary wastewater treatment has been implemented for several communities, but it has been observed that the organic load is high enough so additional steps are required in order to process the wastewater, applied alternatives are either a secondary treatment (biological) or the named Advanced Primary Treatment (APT), the last one is a physicochemical process which allows simultaneous precipitation of several contaminants, since simultaneously use both coagulant and flocculant for enhancing floc formation and settling. According to Vesilind [1] an estimation of associated elimination yields correspond to 60% - 90% in settleable solids (SST), 25% - 40% in biochemical oxygen demand (BOD), 30% - 60% in chemical oxygen demand (COD), 70% - 90% in phosphorus (P), and 80% - 90% in pathogens.

Although an APT process use the same infrastructure than a primary treatment, the fact that municipal wastewater exhibit seasonal variations in its chemical composition leads to the need of running several jar tests in order to find the right reagent dosage, which so far define the amount of sludge produced and its handling procedures. Usually to increase phosphorus removal, the chemical requirements impact increasing 15% the amount of produced sludge since chemical addition may be in excess of stoichiometric requirements [2]. Another problem derived from chemical addition is that sludge dewatering becomes lowered by a raise in salinity, it has been proven that both organic polyelectrolytes and alum provide an improvement on dewaterability [3]. According to Kalders [4] the most important factors in sludge management costs are: 1) physical and chemical characteristics; 2) quantity; 3) legal framework; 4) potential valorization and re-use; and 5) land availability and cost. Therefore, it is important that WWTP operators have the capacity to

predict in a simple way the amount of sludge produced from simple routine procedures such as determining SST, and dry sludge.

This work is an approach to correlate SST and dry sludge amount in order to predict sludge density based on applied coagulant concentration.

2. Methodology

2.1. Reagents

Samples of municipal wastewater were obtained from a WWTP located at the southwest in the city of Puebla. This WWTP applies an APT process using aluminum sulfate as coagulant. By this reason aluminum sulfate is considered as one reagent. In jar tests applied chemical products comprise the coagulants: aluminum sulfate (SAI), iron sulfate (SFe), aluminum polychloride (PAX) and iron polychloride (PIX); also, applied flocculants were cationic and anionic polyacrylamide (CP, AP). All of these chemicals were commercial products provided by Kemira Company.

2.2. Instruments

The jar tests were run in a Kemwater flocculator using the following coagulant concentrations: 40, 60, 80, 100, 120, 140 part per million (ppm) of each coagulant SAI, SFe, PAX, PIX. Flocculants (CP, AP) were added in a dosage of 1 ppm. During experimentation a follow up of chemical parameters was done using portable meters CONDUCTRONIC brand for pH and conductivity; otherwise, color, turbidity, and COD were measured with the appropriate routine in a HACH DR 2500 spectrophotometer. Settleable solids (SST) were measured with an Imhoff cone, and sludge drying was done in a Shell Lab stove.

3. Results and Discussion

It is well known that SAI use produces a pH abatement then it is required to raise the pH before applying the coagulant. Experimental pH data show that SAI and SFe produced a pH drop of about one unit while the polychloride PAX and PIX drop pH in about 0.5 units.

Figure 1 presented results for the observed conductivity values for all coagulant and flocculant combinations. As it can be observed there are two groups one of high conductivity formed by SAI, PIX, PIX + CP, PIX + AP; and one of lower conductivity formed by the Sal + CP, SFe, SFe + CP, SFe + AP, PAX, PAX + CP, PAX + AP. Determined settleable solids amount (SST) are presented in **Figures 2** and **3**. **Figure 2** corresponds to sulfates with and without cationic polymer (CP). As it can be observed inclusion of the CP produces a drop in the amount of SST for SAI at all concentrations; otherwise, SFe is only

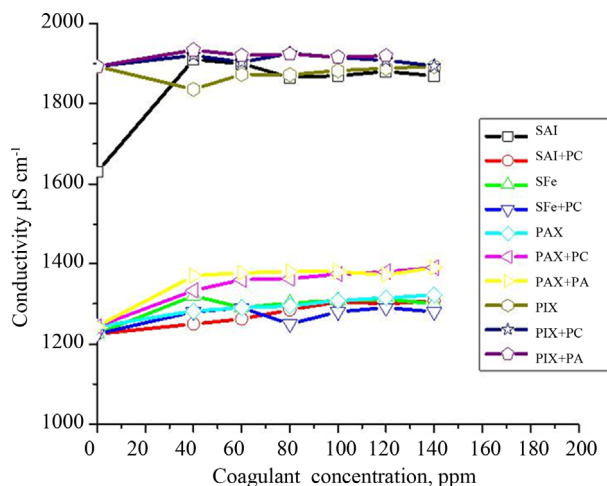


Figure 1. Conductivity results as function of coagulant concentration.

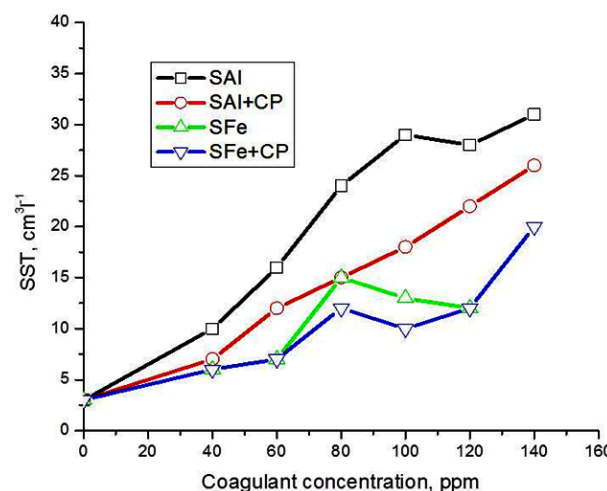


Figure 2. Settleable solids results for SAI and SFe as function of coagulant concentration.

slightly affected at 80 and 100 ppm having a lowering in SST, while all other concentrations provide the same amount of SST with or without CP.

Figure 3 presented obtained results for aluminum and iron polychlorides. As can be observed the PAX SST decrease with the addition of either CP or AP; while the PIX SST amount decrease slightly only with the AP at 80 and 120 ppm coagulant concentration.

Figure 4 presented results for the amount of Dry Sludge (DS) obtained from each jar test, as it can be observed there are two groups the first belongs to the sulfates SAI and SFe in the range of 0.2 to 0.35 g·l⁻¹, and the second one in the range of 0.02 to 0.12 g·l⁻¹ corresponds to the polychlorides PAX and PIX, with and without polymers. Data for SAI exhibit an irregular point at 80 ppm of coagulant, but once the CP is added values become more regular reducing the sludge amount to the range between 0.2 and 0.25 g⁻¹, interval which is lower

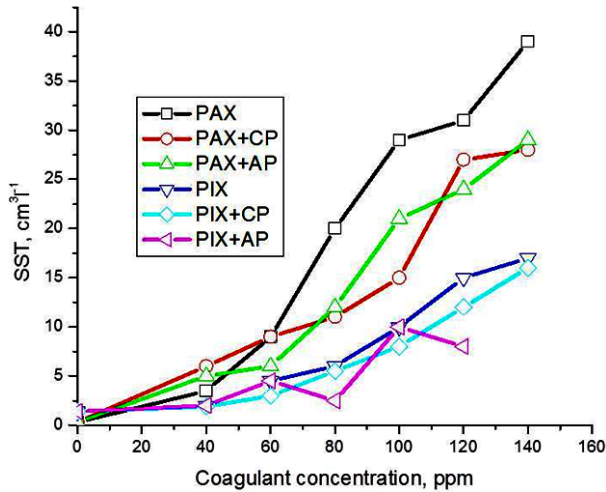


Figure 3. Settleable solids for PAX and PIX as function of coagulant concentration.

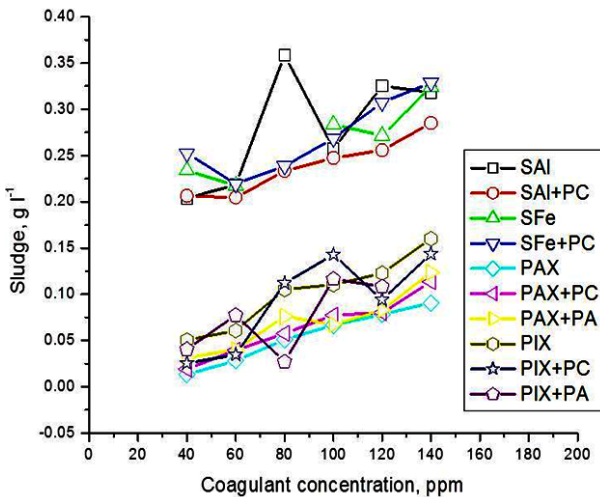


Figure 4. Dry sludge produced at jar tests as function of coagulant concentration.

than the one for SFe which register similar amounts with and without CP. The polychloride PAX produced similar sludge quantities, in which the presence or absence of polymer does not make a great difference. The PIX polychloride produced similar amounts of sludge except at the 80 ppm coagulant in presence of AP, which produced the lower amount of sludge.

Considering the data from SST ($\text{cm}^3 \cdot \text{l}^{-1}$) and sludge mass ($\text{g} \cdot \text{l}^{-1}$) it was estimated the sludge density in $\text{g} \cdot \text{cm}^{-3}$, results are presented in **Figure 5** for the sulfate group, and in **Figure 6** for the polychlorides group.

As it can be observed in **Figure 5** the higher sludge density was obtained with the lower coagulant concentration, use of Sal + CP enable to raise sludge density in about 50%, while at higher concentration sludge density increase is not higher to 30%. Otherwise, SFe exhibit similar amounts of sludge with or without CP at any co-

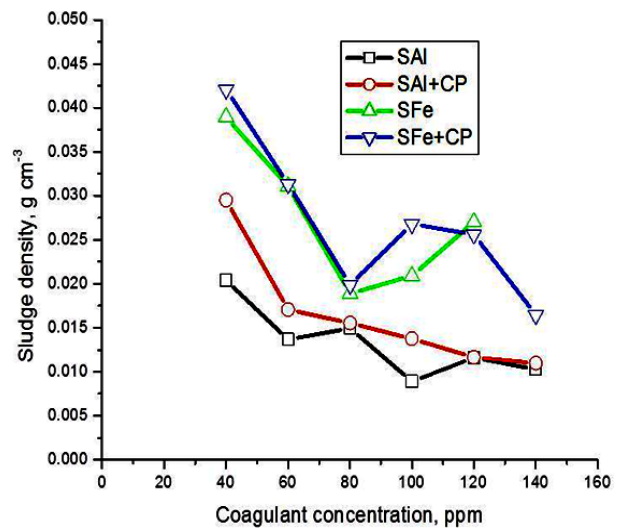


Figure 5. Estimated sludge density from jar tests using SAI and SFe coagulants.

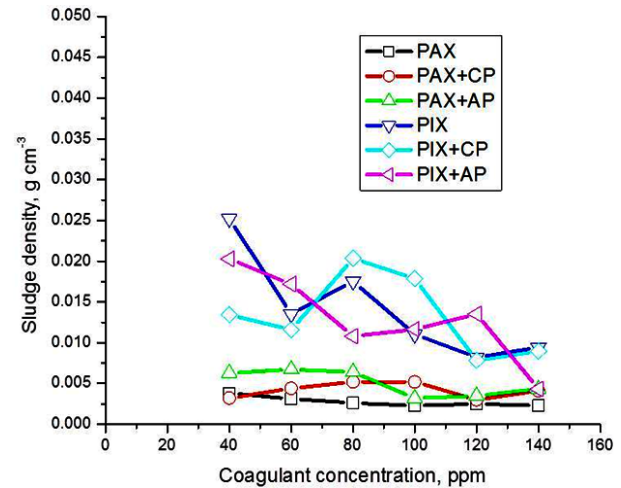


Figure 6. Estimated sludge density from jar tests using PAX and PIX coagulants.

agulant concentration, except for the 100 ppm in which density increases due to the CP presence.

In **Figure 6** it is shown the data for the polychloride coagulants. As it can be observed the sludge density is minimal for the PAX, and addition of CP or AP does not make a great difference in sludge density, obtained values are not greater than $0.005 \text{ g} \cdot \text{cm}^{-3}$ for most coagulant concentrations. Otherwise, the PIX coagulant exhibit higher density than PAX, and for this coagulant the polymer makes a difference since PIX + CP is the combination which provides the lower density at concentrations of 40 and 60 ppm; but for 80 and 100 ppm these concentrations produced a higher sludge density.

4. Conclusions

From conductivity measures it can be affirmed that SAI

and PIX are the coagulants producing a higher salinity condition which should affect sludge dewaterability.

Obtained dry sludge amount is higher when sulfates are used as coagulants either with or without flocculant presence. Also it is observed that Sal + CP produced lower SST volumes than SAl, and so far higher density sludge was obtained. Otherwise, in respect to SAl, SFe produced a lower conductivity condition, and lower SST volumes but calculated sludge density resulted greater than the one obtained for SAl.

From polychlorides data, it can be seen that PAX exhibited an almost uniform conductivity for all coagulant concentrations, and produced higher SST volumes than PIX; also dry sludge was less than the one obtained with PIX; in consequence, calculated sludge density for PAX was lower than the one obtained with PIX.

In general, estimated sludge densities were higher at low coagulant dosages. Also, the higher sludge density corresponds to the sulfates group, since observed range is between $0.01 - 0.045 \text{ g}\cdot\text{cm}^{-3}$; the medium range belongs

to PIX since sludge density is between 0.01 and $0.025 \text{ g}\cdot\text{cm}^{-3}$; finally, the lower density belongs to PAX whose values are in the range of 0.002 and $0.007 \text{ g}\cdot\text{cm}^{-3}$.

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