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Enhancement of Dewatering Properties of Kaolin Suspension by Using Cationic Polyacrylamide (PAM-C) Flocculant and Surfactants.

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Abstract: This paper reports the results on enhancement of dewaterability of sludge using kaolin synthetic sludge as model material by addition of cationic polyacylamide (PAM-C) in the presence of surfactants which are anionic sodium dodecyl sulphate (SDS) and non-ionic Triton X-100. In this study, kaolin synthetic sludge was used as model material as it has similar property of being very difficult to dewater like wastewater treatment plant sludge. Previous study reported that simultaneous addition of PAMC to the surfactants decreased the settling rate and also helped to reduce the moisture content substantially. However, the flocs formed show better filtration and dewatering behavior in terms of reduction in specific cake resistance to filtration (SRF) and cake moisture content. In this study, the kaolin synthetic sludge dewaterability was enhanced by addition of flocculant and surfactant. The results of different concentration of PAM-C – SDS combinations used were compared and optimized. Sludge dewaterability was expressed in terms of settling rate and specific resistant of cake to filtration (SRF) for various concentration and combination of dewatering aids. The settling rate obtained for PAMC as an optimum dosage of 1mg/g. The settling rate of kaolin suspension could be improved up to 10-times by flocculation of kaolin with flocculants and surfactants.

Key words: *Dewatering, flocculants, surfactants*

INTRODUCTION

Sludge accumulates as a residue in all sorts of wastewater treatment. Sludge comprises the solids and colloids separated from wastewater as well as substances from biological and chemical operation units. Some sludges are produced during wastewater treatment, including primary sludge, which comprises settleable solids removed from the primary clarifier, and secondary sludge, which comprises biological solids generated in the secondary wastewater treatment plant. The volume of sludge, produced throughout the wastewater treatment process, amounts to about 1-2% of the total wastewater flow (Krylów and Fryzlewicz-Kozak, 2007). Therefore, sludge handling and management at the wastewater treatment plant is a widely discussed issue. Optimum sludge handling is a process that results in a low sludge mass for disposal, by means of a low solid mass and moisture content of the dewatered sludge cake. In addition, optimum sludge handling is achieved if the process involves low doses of conditioner and produce high dewatering rate (Metcalf and Eddy, 2003). At the end of the wastewater treatment process, the produced sludge consists almost 97 % of water (Davis, and Cornell, 2008). Hence sludge treatment is an essential process to separate the bulk amount of water from the solid residue to reduce the volume of the sludge and also help to reduce the moisture content which further eases for handling and transportation

The kaolin suspension was used in this experiment as model material of wastewater sludge. This synthetic sludge was treated with cationic polyacrylamide (PAM-C) flocculant in presence of different type of surfactants. The use of polymers in water treatment can achieve rapid flocculation and result in better settling or filtrating behaviors (Zhu, *et al*., 2009). The surfactants used are anionic sodium dodecyl sulphate (SDS) and Triton X-100. Experiments were done in laboratory to find the optimal dosage of flocculants-surfactants combination on kaolin suspension. The sludge filterability and dewaterability was measured by in response of settling time (cm/s), specific resistance of cake to filtration (SRF) (m/kg) and moisture content (%). Neutralization of charge and formation of bridge between the particles are the main mechanisms during the flocculation process (Qian, *et al.,* 2004). The results of each run were compared with control and with each other. At the end of the experiment, the optimal dosage of flocculants-surfactants combination was tested on actual sludge from wastewater treatment plant (WWTP).

Methods:

The kaolin used in this study is refined kaolin, AKIMA 35 which was supplied by Associated Kaolin Industry (AKI) Sdn. Bhd. Malaysia. The sample was analyzed using JEOL Scanning Electron Microscopes and

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Laser Particle Sizer ANALYSETTE 22 NanoTec. Cationic Polyacrylamide (PAM-C) used in this study is ARONFLOC C 4913, was obtained from Indah Water Konsortium (IWK) Malaysia, which was supplied by MT AquaPolymer, Inc., Japan. Anionic Sodium Dodecyl Sulphate (SDS) and non-ionic Triton X-100 were obtained from Merck Malaysia Sdn. Bhd.

For kaolin suspension samples, 5% (w/v) kaolin suspension was prepared. Then, the requisite amount of flocculants was added into 1000 mL samples in 1000 mL beaker followed by stirring at 250 rpm for 10 minutes to produce homogenous mixture. Flocs structures of settled sludge were observed for each sample.

The entire suspension was then transferred to a graduated cylinder and allowed to settle after inverting the cylinder five times for sedimentation. A clear liquid slurry interface can be seen descending. The height of this interface was noted at a given interval of time. Settling rates were estimated from the slope of the straight-line portion of the plot interface height versus settling time. After the sedimentation, the suspension was allowed to stand without disturbance for 24 hours. Duplicate measurements were made under similar experimental conditions. Then, the sediment was collected and tested in filtration studies.

All the filtration experiments were carried out by vaccum filtration unit (Buchner Funnel Test). The Buchner Funnel Test equipment consists of a Buchner flask, Buchner Funnel and a vacuum pump. A Buchner Funnel is mounted on top of the flask and the funnel is fitted with a Whatman No 41 filter paper. The kaolin suspension after conditioned was poured into the filter holder under desired pressure difference applied by vacuum. The volume of filtrate collected in the flask was recorded at a regular time interval (Besra, *et al*., 2003). The data obtained is used to calculate the specific cake resistance using the integrated form of Darcy's equation (1).

$$\frac{t}{V/A} = \frac{\mu\alpha\rho_c}{2\Delta P}\left(\frac{V}{A}\right) + \frac{\mu Rm}{\Delta P} \quad (1)$$

Where *V,* volume of filtrate collected in time *t,* μ is the viscosity of the fluid. ΔP is the pressure difference across the filter cake and filter medium, filter area *A*, R_m is the medium resistance and α is the specific resistance of filtration, ρ_c is the mass of dry cake solids per volume of filtrate.

By plotting *t/V* versus *V* resulted in a straight line whose intercept on the y axis give medium resistance *Rm.* α is calculated from the slope using the equation (2).

$$\alpha = \frac{2\Delta P(slope)}{\mu\rho_C} \quad (2)$$

When the slurry passes through the filter medium, a pressure gradient set up across the medium. Because of this solid begin to build up and cake is formed. This type of filtration sometimes called as "dead end" filtration (Roger, *et al*., 2003).From the moment when liquid disappeared from the top surface of the cake formed, a dewatering time of 10 min was allowed and the cake was carefully removed, weighed and dried at 105° C until it attained a constant weight. Moisture content of the cake was determined from the loss in weight on drying (Besra, *et al*., 2002).

Results:

In jar test trials, different amounts of PAM-C, SDS and TX-100 ranged from 0.25 to 1.25 mg/g were added in one liter of water containing 50 gm of Kaolin in each case. 250 rpm was set for 10 minutes. Then the solution is transferred to a graduated cylinder and settling rate at regular interval of time in the cylinder was noted. Settling rate is obtained from the slope of the straight line portion of the plot of interface height versus settling time Fig.1.

The addition of flocculants and surfactants in kaolin exhibit different range of sediment volume as shown in the Fig. 2. The unflocculated kaolin exhibit 2.2ml of sediment volume. Addition of conditioners improved the sediment volume except in surfactants alone because of the formation of small flocs compared with PAMC. The graph of sediment volume shows that increasing in PAM-C concentration increases the sediment volume until a certain point, after which the sediment volume starts to remain constant.

The moisture content of kaolin suspension increases with increasing concentration as showen in Fig 3, the specific resistance of filtration decreases at the initial stages and attain a minium value range between 0.25 to 0.5mg/g, further increase of concentration increase the SRFas showen in Fig 4.

After the entire kaolin test, the validation of the kaolin results were applied on the actual sludge collected from Titiwangsa Sewage Treatment Plant, a domestic plant under Indah Water Konsortium Malaysia. The validation of sludge at 0.75mg/g with same chemicals that used for kaolin and obtained the results given as tables 1-4.

Conclusion:

From the above studies, it is clear that flocculants and surfactants can improve the settling of kaolin. Especially in the case of PAMC, it is better as a flocculant to improve the settling rate with out the other surfactants like SDS and TX-100. Both of these make small flocs when compared to PAMC. The Validation studies using the actual sludge that is from a domestic waste water treatment plant(WWTP) was also comparable to the model substance.

Table 1: Settling Rate for concentration of sludge 0.75mg/g. Settling rate for control = 0.011cm/s

Concentration 0.75 mg/g	PAMC	SDS	TX-100	PAMC+SDS	PAMC+SDS+TX-100
Settling rate (cm/s)	0.035	0.057	0.012	0.015	0.016

Table 2: Sludge Sediment Volume for Conc 0.75mg/g. Sediment Volume for control = 6.808 cm^3/g

Concentration 0.75 mg/g	PAMC	SDS	TX-100	PAMC+SDS	PAMC+SDS+TX-100
Sediment volume(cm^3/g)	7.4	11.84	12.728	13.32	13.024

Table 3: Sludge Moisture Content for conc 0.75mg/g. Sludge moisture for control (%) = 40.2847

Concentration 0.75 (mg/g)	PAMC	SDS	TX-100	PAMC+SDS	PAMC+SDS+TX-100
Sludge moisture(%)	65.3597	61.8341	55.8397	42.1012	67.5998

Table 4: Specific Resistance of Filtration(α) for Conc 0.75mg/g. SRF(α) for control = 4.60E+11

Concentration 0.75(mg/g)	PAMC	SDS	TX-100	PAMC+SDS	PAMC+SDS+TX-100
SRF (α)	1.12E+10	1.18082E+11	4.88E+11	2.677E+11	1.58766E+11

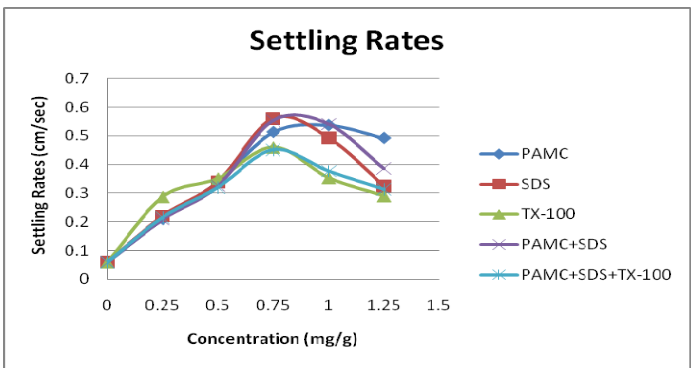

Fig. 1: Settling Rates for Kaolin solution.

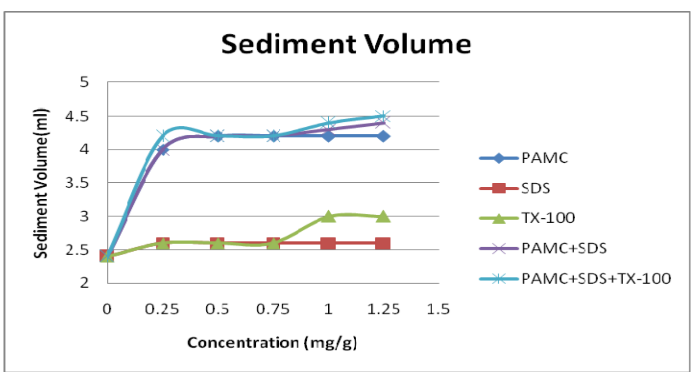

Fig. 2: Sediment Volume for Kaolin solution.

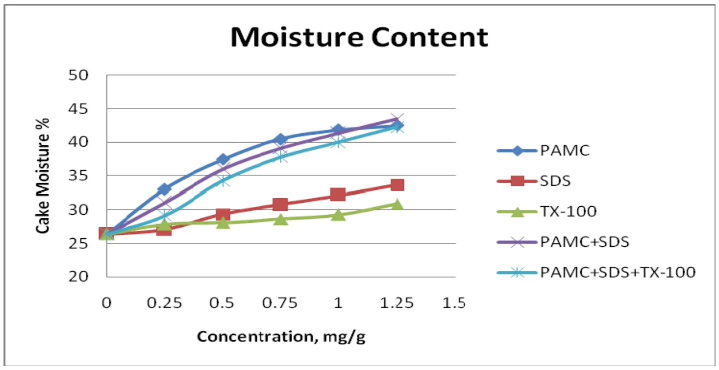

Fig.3: Moisture content for Kaolin solution.

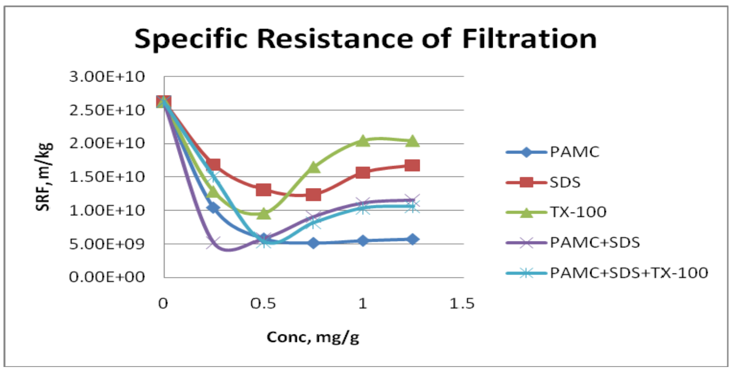

Fig. 4: Specific Resistance of Filtration (α) for Kaolin solution.

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