Impact of Coagulation Mixing and Time on CST Values

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Abstract - The influence of rapid mixing velocity and rapid mixing time has been investigated in this study to assess corresponding impacts on sludge dewaterability. The CST (Capillary Suction Time) apparatus was used as tools to measure sludge dewaterability. The results indicate that rapid mixing velocity and rapid mixing time have varying degrees of influence on the CST value, and hence, on sludge dewaterability. Correlation coefficients show that by including the initial CST value (0 rpm), rapid mixing velocity appears to have a more significant impact on the CST value than rapid mixing time. By excluding the initial value, the impact of rapid mixing velocity and rapid mixing time are similar, where the gradual increase in rapid mixing velocity and rapid mixing time appears to have very little influence on sludge dewaterability.

***Keywords* – coagulation, coefficient correlation, initial value, mixer shape, sludge**

I. Introduction

GENERALLY, the water content in sludge is approximately 95%, which needs to be reduced prior to disposal and this accounts for almost half of the treatment costs of dewatering and disposal (Chen et al., 2010).

Sludge dewaterability is very dependent on sludge/floc characteristics, in particular size distribution and the presence of small particles (Jin et al., 2004), which are determined by the specific coagulation process mechanism. Coagulation is a process in which all the reactions and mechanisms have the purpose of producing an agglomeration of contaminants or particles (AWWA, 1999; Gray, 2005).

The coagulation process consists of two-stage mixing processes: rapid mixing (coagulation) and slow mixing (flocculation). Rapid mixing is employed at the first stage to disperse the coagulant in the water. Slow mixing is used as a second stage to stimulate the agglomeration of particles and to encourage sedimentation.

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At a fundamental level, the rapid mixing velocity provides interaction between molecules and particles in the water and a coagulant (Amirtharajah & Jones, 2000). Alongside the rapid mixing velocity, the rapid mixing time also has an important role in the coagulation process (Francois & Van Haute, 1984; Rossini et al., 1990; Kan et al., 2002a; Chakraborti et al., 2003; Yu et al., 2011). Rapid mixing time is the time needed to disperse a coagulant into water.

Although rapid mixing velocities and rapid mixing time have been proven to have an impact on the floc conditions (Kan et al., 2002b; Bouyer et al., 2005; Kim et al., 2006; Li et al., 2006; Francois & Van Haute, 1984; Rossini et al., 1990; Kan et al., 2002a; Chakraborti et al., 2003; Yu et al., 2011), the correlation between rapid mixing velocity and sludge conditioning in the coagulation process are still uncertain. To ensure high quality results in sludge dewaterability, sufficient mixing is needed. Based on the correlation between rapid mixing and sludge conditions, this raises a question about the effect of rapid mixing and time on sludge dewaterability. This research explores the influence of rapid mixing velocity and rapid mixing time on sludge dewaterability.

II. MATERIALS AND METHODS

A. *Coagulants and Mixers*

The coagulants ferric chloride (ferric) was provided by Sigma Aldrich Company Ltd. (The Old Brickyard, New Road, Gillingham, Dorset SP8 4XT, England, UK). Ferric stock solution was prepared by diluting ferric concentrates with distilled water. Five shapes of mixer (radial, axial, wheel, magnetic and 3-blades) have been as one of the variables in this research (Fig 1). The mixer types and shapes have been chosen based on the information provided by companies producing and/or selling standard mixers used by the water and wastewater industry.

Radial Axial Wheel Magnetic 3-blades

Fig 1. Mixer types in experimental work

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B. Coagulation Experiments

Most results presented in this research were obtained from three repeat coagulation experiments and from three readings. Some of the results presented are based on more than three readings, primarily due to high variability in the results.

Rapid Mixing Velocity

To investigate the influence of rapid mixing velocity on coagulant performance, a 100ml water sample was poured into a glass beaker followed by the addition of the coagulant. After adjusting the pH with sulphuric acid (H_2SO_4) or sodium hydroxide (NaOH) to reach a pH value of approximately 6.5, the fluid was mixed rapidly at a variable high rate (60, 65, 70, 75, 80, 85, 90, 95 and 100 rpm) for 60 s and then at a moderate rate of 50 rpm for 15 minutes to accommodate the agglomeration process.

Rapid Mixing Time

Tests to examine the influence of rapid mixing time utilized a 100 ml water sample contained within a glass beaker, to which was added H_2SO_4 or NaOH to adjust the pH. The coagulant was subsequently added to the water sample. Once a pH of 6.5 was reached, the sample was mixed rapidly at a range of times (10, 20, 30, 40, 50, 60, 70, 80, and 90 s) with a constant 100 rpm rapid mixing velocity, and then at a slower rate of 50 rpm for 15 minutes to accommodate the agglomeration of flocs.

C. CST Measurement

A Triton Type 304B Capillary Suction Timer apparatus and Whatman 17 chromatographic paper were used in this investigation (Triton Electronics Ltd., Bigods Lane, Great Dunmow, Essex CM6 3BE, UK) (Fig 2).

Fig 2. Capillary Suction Time Apparatus

D. Statistical Analysis

In this investigation, Pearson’s correlation coefficient was used to describe the strength of the relationship between any two variables. The calculation used IBM SPSS Statistics version 20.

III. Results and Discussions

A. Coefficient correlation

Rapid mixing has an important role in water coagulation in dispersing the coagulant into the water; the better the dispersal, the better the agglomeration of the contaminant in the water (AWWA, 1999). Statistical analysis, specifically the coefficient of correlation, was used to explain the correlation between different rapid mixing velocities and sludge dewaterability. The calculation was in two parts (Table 1). The first used an initial CST value with 0 rpm rapid mixing velocity or 0 minute rapid mixing time, and the second was without the initial value. The purpose of including the initial value was to see the effect of rapid mixing velocity and time employment on the CST value as well as not including the initial value investigated the effect of increasing rapid mixing velocity and time on the CST value.

TABLE 1. THE IMPACT OF RAPID MIXING VELOCITY ON CST VALUE.

Mixer	r (with 0 rpm)		r (without 0 rpm)	
	velocity	time	velocity	time
Radial	-0.74	-0.58	0.26	-0.47
Axial	-0.87	-0.53	0.14	-0.09
Wheel	-0.89	-0.73	-0.15	-0.83
Magnetic	-0.89	-0.52	-0.15	-0.02
3-blades	-0.87	-0.58	0.32	-0.51

Table 1 shows the result of correlation coefficient of CST value and also the comparison of the initial value impact on the calculation. By including the initial CST value, the rapid mixing velocity has a beneficial impact on sludge dewaterability. Increasing rapid mixing velocity results in decreasing the CST value. On rapid mixing time, the coefficient of correlation value with 0 rpm shows a reasonable association between rapid mixing time and CST value. The correlation coefficient for rapid mixing velocity is higher than for rapid mixing time. This means that the implementation of rapid mixing velocity is more important in increasing sludge dewaterability than the implementation of rapid mixing time. This finding is supported by Mhaisalkar et al. (1991) and Liang et al. (2009) where rapid mixing velocity was found to have a more important influence compared to rapid mixing time on coagulation process. Wang et al. (2009) and Sawalha (2010) also stated that mixing influences sludge dewaterability and to ensure high quality results in sludge dewaterability testing sufficient mixing is needed to increase sludge dewaterability.

By excluding the initial value, the rapid mixing velocity is not important in increasing sludge dewaterability. Increasing the rapid mixing velocity, in general, increases the CST value. This was also shown by the rapid mixing time correlation coefficient. Without the inclusion of the rapid mixing time initial value, all the coefficient of correlation values decrease, even though this decrease is not as much as occurred with the rapid mixing velocity coefficient of correlation. These data suggest that the implementation of rapid mixing velocity and rapid mixing time is very important in decreasing the CST value, but its gradual increase does not have any essential impact when using metal-based coagulants. It seems that as long as the rapid mixing velocity and rapid mixing time has been applied, the CST value will decrease. This means that a low rapid mixing velocity and time values are sufficient to decrease the CST value.

This might be due to the high turbid water sample. Kaolin solution has a turbidity higher than 1000 NTU. Mhaisalkar et al (1991) and Muyibi & Evison (1995) stated that highly turbid water does not require a very high mixing intensity. This is due to the fact that the number of collisions is high in highly turbid water, so that no extra agitation is needed to stimulate the contact between the contaminant particles.

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