

# Effect of Ionic Strength on Settling of Activated Sludge

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## ABSTRACT

Structural properties of activated sludge flocs were found to be sensitive to small changes in ionic strength. This study investigates the effect of ionic strength on settling of activated sludge. Samples were taken from activated sludge process of Ghazvin Sasan soft drink wastewater treatment plant, then treated with different ionic strengths of KCl and CaCl<sub>2</sub> solution, after that the turbidity of supernatant was measured. The results indicated that low ionic strength resulted in a steeper slope of the accumulated turbidity data for both KCl and CaCl<sub>2</sub> as a result of a release of floc fragments and free cells into the supernatant, which did not precipitate during the incubation period. By increasing the ionic strength, the sedimentation improved because of less fragmentation of the sludge flocs. Also at low ionic strengths, the dissociation coefficient was high as a result of a substantial fragmentation of the sludge flocs. The dissociation of the flocs decreased as the ionic strength increased, resulting in a minimum of floc degradation in ionic strength between 0.006 and 0.06M.

**Keywords:** *Ionic strength, Settling, Activated sludge, Soft drink wastewater treatment plant*

## INTRODUCTION

Changes in ionic strength and ionic composition have been reported to influence activated sludge stability and the solid-liquid separation processes. Reduced ionic strength in the sludge water affects the floc strength, causing a weakening of the flocs, a deflocculation and an increased turbidity in the water phase (Eriksson et al., 1992; Zita and Hermansson, 1994).

The mechanism behind the observed deflocculation at reduced ionic strength has recently been suggested by Zita and Hermansson (1994)

thickness according to the DLVO theory. They also found that increased ionic strength promoted a flocculation, probably due to a reduction in the double layer thickness, even though it was observed that, at high ionic strength, deflocculation reoccurred. This confirmed the observations of Bruus et al. (1992), who found that increasing concentrations of cations, such as magnesium and potassium, also could bring the flocs to deflocculates, and a mechanism involving ion exchange of specific adsorbed ions (mainly calcium) was suggested. The stability of the flocs depends on the forces gluing the floc components together in the three-dimensional matrix.

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A typical floc is 80-120  $\mu\text{m}$  in diameter and the components are bacteria, organic fibers, inorganic particles and extracellular polymeric substances (EPS) arising from the bacteria or from wastewater (Jorand et al., 1995; Frolund et al., 1996).

Several mechanisms are suggested to be involved in the floc formation. It involves the production of extracellular polymers (Morgan et al., 1990), bridging of negatively charged EPS components with divalent cations such as calcium (Forster and Lewin, 1972; Kakii et al., 1985), DLVO-type interactions (Zita and Hermansson, 1994) and hydrophobic interactions (Urbain et al., 1993).

In the present work, the impact of minor changes of ionic strength on settling of activated sludge was studied.

Ionic strength is an empirical measure of the interactions among all the ions in a solution which causes deviation from ideal behavior. The ionic strength and  $\mu$  are the characteristic of the solution and is defined as  $\mu = \frac{1}{2} \sum C_i Z_i^2$ , where  $C_i$  is the molar concentration of the  $i^{\text{th}}$  ion, and  $Z_i$  is its charge (Sawyer et al., 2000).

## MATERIALS AND METHODS

The wastewater of Sasan soft drink treatment plant in Ghazvin, Iran, is treated by primary sedimentation followed by a biological selector and an activated sludge process with a solid retention time of 5-10 days. The aerations tanks are aerated by surface mechanical aerators. The sludge passes through the aeration and settling tanks. COD, BOD and MLSS were 3300, 2500 and 3000 mg/l, respectively.

The pH was 6.8-7.4; low dissolved oxygen concentration was not detected during the sampling period.

Samples were treated with different ionic strengths of KCl and  $\text{CaCl}_2$  solutions. The sludge was gently mixed and divided into aliquots of 10 ml. After 15 min. of sedimentation, 6 ml of the supernatant was removed and the

turbidity was measured by spectrophotometry at 420 nm (LKB Nova spec). Then adding KCl, the samples were gently mixed and flocs were allowed to settle for 15 min. This procedure was repeated 10 times. The different series of ionic strengths were  $0.06 \cdot 10^{-3} \text{M}$ ,  $0.6 \cdot 10^{-3} \text{M}$ ,  $6 \cdot 10^{-3} \text{M}$ ,  $60 \cdot 10^{-3} \text{M}$  for KCl and  $0.07 \cdot 10^{-3} \text{M}$ ,  $0.7 \cdot 10^{-3} \text{M}$ ,  $7 \cdot 10^{-3} \text{M}$ ,  $70 \cdot 10^{-3} \text{M}$ , for  $\text{CaCl}_2$ . Untreated portions of activated sludge were used as controls in this test to measure the possibility of a disintegration of the sludge flocs as a result of the sample treatment. Equal amount of activated sludge (10 ml) were allowed to settle for 15 min and the turbidity in the supernatant was measured as described above. The samples were mixed and again allowed to settle without addition of salt solutions.

The sludge was taken from the end of the aeration tank and transported to the laboratory. All experiments were performed at ambient temperature, varying between 15 to 20°C. The turbidity, measured after each round of treatment was accumulated to show the total dissociation of the flocs up to each time point during the experiment. The accumulated turbidity made it possible to calculate a dissociation coefficient. The dissociation coefficient for each treatment is defined as the slope of the calculated straight line (using standard linear regression) of the accumulated turbidities plotted against increasing ionic strength in the salt solution.

## RESULTS

In the treatment with KCl and  $\text{CaCl}_2$ , the turbidity in the supernatant depended on the ionic strength in the medium (Figs1 and 2). Low ionic strength resulted in a steeper slope of the accumulated turbidity data for both KCl and  $\text{CaCl}_2$  as a result of a release of floc fragments and free cells into the supernatant, which did not sediment during the incubation period. As we increased the ionic strength, the sedimentation improved because of less fragmentation of the sludge flocs.

Also, the concentration of free cells decreased in the supernatant as we increased the ionic strength. These effects resulted in a less steep slope of the accumulated absorbance compared with the low ionic strength treatments. The accumulated turbidity data showed similar trends for both KCl and CaCl<sub>2</sub>. For the control samples of untreated sludge, the turbidity in the supernatant was fairly constant and no increase in turbidity could be detected during the test.

The dissociation coefficient (see material and methods) is a conventional way to illustrate the stability of the flocs in different ionic strengths (Fig. 3.) At low ionic strengths, the dissociation coefficient is high as a result of a substantial fragmentation of the sludge flocs. The dissociation of the flocs decreases as the ionic strength increases, resulting in a minimum of floc degradation between 0.006 and 0.06M.

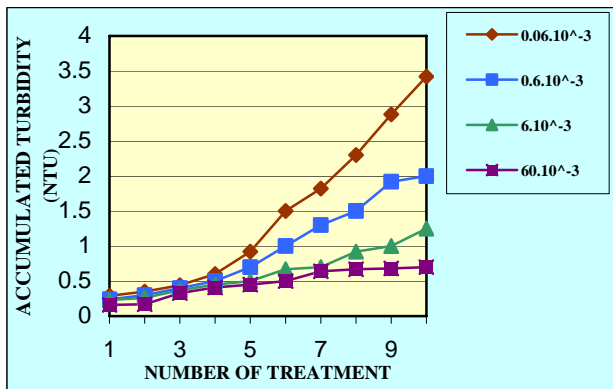


Fig. 1: Accumulated turbidity in the supernatant as a function of ionic strength. KCl solution was used for treating the flocs

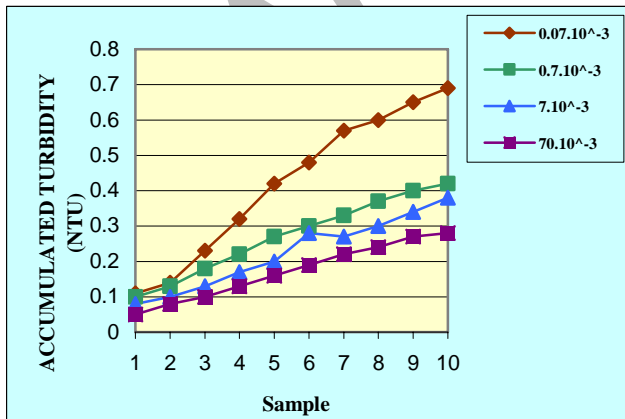


Fig. 2: Accumulated turbidity in the supernatant as a function of ionic strength. CaCl<sub>2</sub> solution was used for treating the flocs

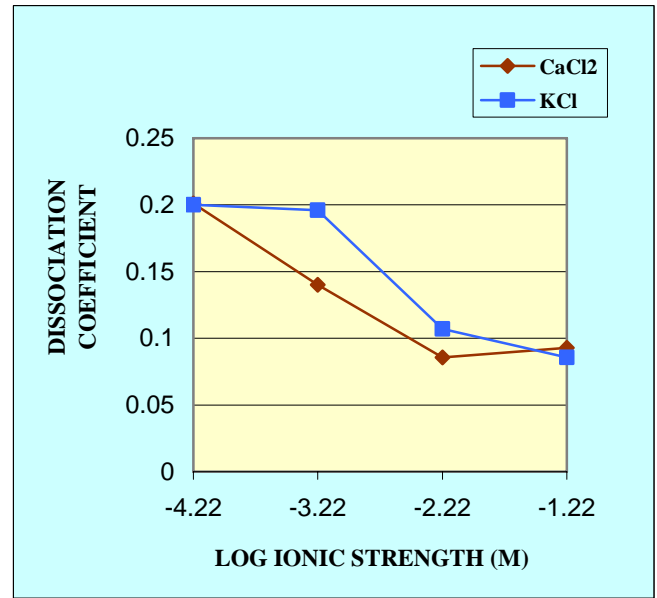


Fig. 3: Dissociation coefficient for activated sludge as a function of ionic strength.

## DISCUSSION

The detachment of material from the flocs was affected by ionic strength of the medium in a way that strongly suggested that interactions between the floc components could be explained by the general DLVO theory (Loosdrecht et al., 1989).

By increasing the concentrations of electrolytes, which resulted in a compression of the electrical double layers around all surfaces, the stability of the flocs increased. Below an ionic strength of 0.06 M the stability of the flocs increased with increasing ionic strength. This was shown for both mono and divalent cations.

The ambient ionic strength in the wastewater was within the range where the DLVO theory is applicable, and therefore the stability of the flocs could well be affected by differences in the ionic strength of the influent wastewater.

In the intermediate interval, approximately 0.006 to 0.06M, the stability of the flocs was constant and changes in ionic strength did not affect them particularly. This could be the result of the small changes in double layer thickness.

Loosdrecht et al (1989). Showed that reversible adhesion of bacteria to a surface increased with

increasing electrolyte concentration and finally reached a saturation value in the interval of 10 to 100 mM. Our results agree well with this finding result, indicating that there are similar mechanisms involved in the maintenance of the flocs. We are of course aware of the high complex situation in wastewater, with various compositions and structures of the sludge flocs, through fluctuations in one wastewater treatment plant and between different plants, and we do not expect that the DLVO theory can explain all interactions within the flocs.

It is probable that the outer parts of the flocs are held together in a reversible manner and that this is the part that could be affected by the differences in the double-layer thickness, rather than the inner parts where the polymer matrix extensively developed (Eriksson and Hardin, 1989).

The polymer matrix in the central parts mediate a close contact between cells, a situation that not well described by the DLVO theory.

Surface charge density, surface potential, and ionic composition of the solution (through its effect of  $k$ , where  $1/k$  is the Debye length or the double-layer thickness) are interrelated (Ross and Morrison, 1988). However, the surface charge is affected only by the adsorption of potential-determining ions. Therefore, if inert electrolyte is added,  $1/k$  will decrease, and the surface potential will decrease without any change in the surface charge density. An increase in the ionic strength therefore has double effect on the interaction between two surfaces, a decrease both in the thickness of the double layer and of the surface potential (Ross and Morrison., 1988).

The result showed that ambient ionic strength in the effluent wastewater was within the range where the DLVO theory was applicable and that the wastewater followed the general trend of the KCl and CaCl<sub>2</sub> treatments. Therefore, the stability of the flocs in wastewater in situ could well be affected by differences in the ionic strength of the influent wastewater.

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