Effect of solution physical chemistry on the rheological properties of activated sludge

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Abstract

Knowledge on rheological properties of sludge is important for the design of pumping and transport facilities and as a tool in process control during treatment. Concentrated activated sludge is known to behave as a non-Newtonian material. The contribution to non-Newtonian behaviour is believed to originate from the colloidal properties of solids more than from the molecular properties of the suspension. Considering that the colloidal properties of sludge depend on factors like pH, conductivity, solids concentration and flocculation properties, this study examines the effects of these variables on the rheology of activated sludge. Results show that the rheograms obtained fit best to a power law model indicating that the flow of activated sludge can best be expressed by the pseudoplastic flow model. It is also observed that the apparent viscosity increases sharply with the increase of solids concentration. From the pH values studied, the one that causes the lowest viscosity is the pH 5.5. As the pH increases, the viscosity measured increases considerably. This makes sense considering that the isoelectric point of bacteria is at pH 2-4. Conductivity is also found to affect the viscosity greatly; such that as the conductivity increases, the apparent viscosity decreases. Finally, experimental results reveal that the presence of extracellular polymers and the flocculated nature of activated sludge affect its viscosity.

Introduction

Understanding of the rheological properties of sludge is not only important in the design of pumping and transport facilities but also critical for controlling treatment processes like the polymer dose assessment for sludge conditioning prior to dewatering. A property this important did not receive the deserved attention up until recently, mainly due to the difficulties associated with the measurement of viscosity especially of biological sludges. Activated sludge is a biological suspension of flocs having irregular shapes and various sizes that change over time or when the environmental conditions change. Besides, the concentration of solids present in the slurry is another factor of importance in determining the flow properties. A very thin activated sludge may behave very close to water (Newtonian behaviour) in terms of rheological properties; however, with increasing solids concentration, activated sludge exhibits non-Newtonian flow character. Activated sludge has been identified as either a plastic (Dick and Ewing, 1967; Unno and Akehata, 1985; Dick, 1986) or a pseudoplastic (Behn, 1962; Moeller and Torres, 1997) non-Newtonian fluid.

The contribution to non-Newtonian behaviour is believed to originate from the colloidal properties of solids more than the molecular properties of the suspension (Hiemenz and Rajagopalan, 1997). The colloidal properties of sludge that may affect the rheological characteristics are particle size, shape, flexibility, surface charge, solvation and flocculation. Furthermore, the rheological behaviour of colloidal dispersions is summarised to depend mainly on (Shaw, 1992):

- Viscosity of the dispersion medium
- Particle concentration
- Particle size and shape
- Particle-particle and particle-dispersion medium interactions.

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From these factors, the first one, the dispersion medium viscosity is the simplest to deal with. For activated sludge the dispersion medium is water and being a Newtonian fluid, water has a fixed viscosity at a fixed temperature. The second factor, the solids concentration, has been studied more than the other factors for activated sludge and its effect is pretty well documented (Dick and Ewing, 1967; Dick and Buck, 1985; Lotito et. al., 1997). The third factor, particle size and shape, is a very difficult aspect of activated sludge to study. Activated sludge has a broad particle size distribution, which varies over time and according to the physical and chemical factors like shear and solution chemistry. Particle-particle and particle-dispersion medium interactions also depend on particle properties as well as solution physical chemistry. The last two sets of parameters are pretty complicated and have not been studied adequately.

Considering that the colloidal properties of sludge depend on factors like pH, ionic strength, solids concentration and flocculation properties, this study was undertaken to evaluate the effects of these variables on the rheology of activated sludge.

Materials and methods

The sludge used in the experiments was a waste activated sludge taken from a municipal wastewater treatment plant. The sludge was concentrated to about 2% solids by gravity settling. Concentrated sludge was then connected to an aeration pump and aerated during the study; its supernatant was stored in the refrigerator and used to dilute the sludge samples when necessary. The tests were conducted in the course of 3 to 4 d. Sludge samples were discarded at the end of each set of experiments and always a new sample was brought to the laboratory for the next set.

Rheological properties of sludge were determined by using a rotational viscometer (Brookfield LVDVII+ equipped with ultra-low viscosity adapter). Viscometer spindle diameter was 2.5cm, with a gap size of 0.15cm between the spindle and the reservoir. Shear stress-shear rate relationships were determined at six different rotational speeds, corresponding to six different shear rates. Shear