A Novel Technique to Measure and Characterize Flocs and Settling Behavior for Design of Sedimentation Basins

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Abstract

The settling of suspended particles in a tank is a complex process. Due to the development of variable porosity with variable source water containing organic and inorganic contaminants, shape, size, and uncertainty in the estimation of turbulence, it is difficult to predict the settling rate of real aggregates, which are often fragile, highly porous, and non-spherical. Often, Stokes’ law is used to determine the settling velocity of particle assuming flocs are dense spheres. This study presents results of particle settling rate from in-situ measurements and characterized with fractal geometry.

Objectives

Characterization of flocs using nonintrusive measurement technique such as image analysis method provides understanding of particle settling behavior. This study explores the shape effect, as described by fractal geometry, is likely contributing to an increase in settling velocity with particle size. The areas measured using an in-situ imaging method and the calculated areas were found to be different and thus, it is difficult to analyze the behavior existing during settling. It is found that the settling velocity relative to Stokes’ law, decreases with increases in the particle size and with irregularities in the particle boundaries. Results from the present study support an understanding of the settling velocity by relating it to a fractal description of the aggregate shape and size in suspension and to the observed settling velocity of each particle with particle size for different natural suspensions.

Approach

Settling velocity of suspended natural particles is a complex process that depends on geometric and physico-chemical properties of the particles, as well as water chemistry and flow conditions. The settling of natural particles is complex due to the development of variable porosity with variable source water containing organic and inorganic contaminants, shape, size, and uncertainty in the estimation of turbulence. It is difficult to predict the settling rate of real aggregates, which are often fragile, highly porous, and non-spherical. Often, Stokes’ law is used to determine the settling velocity of particle assuming flocs are dense spheres. This study presents results of particle settling rate from in-situ measurements and characterized with fractal geometry.

Fig. 1. Distribution of projected area for suspensions in: (a) Buffalo River, (b) Lake Ontario, (c) Lake Erie, (d) Lake LaSalle, and (e) Montmorillonite clay. The bars represent (a) classified and (b) measured

Fig. 2. Image of particles settling through water column (a) Buffalo River, (b) Lake Ontario, (c) Lake Erie, (d) Lake LaSalle, and (e) Montmorillonite clay. The bars represent (a) classified and (b) measured

Fig. 3. Distribution of projected area for suspensions in: (a) Buffalo River, (b) Lake Ontario, (c) Lake Erie, (d) Lake LaSalle, and (e) Montmorillonite clay. The bars represent (a) classified and (b) measured

Fig. 4. Distribution of particle size for different environments. a) Measured, b) Calculated, c) Montmorillonite clay, d) Lake Ontario, e) Lake Erie, f) Lake LaSalle, and g) Buffalo River

Fig. 5. Circle of given area and projected area of measured particles and calculated particles from various samples: (a) Buffalo River, (b) Lake Ontario, (c) Lake Erie, (d) Lake LaSalle, and (e) Montmorillonite clay

Fig. 6. Measured settling velocity profiles for suspensions in: (a) Buffalo River, (b) Lake Ontario, (c) Lake Erie, (d) Lake LaSalle, and (e) Montmorillonite clay. The bars represent (a) classified and (b) measured

Fig. 7. A range of sediment characteristics including settling velocity (ws) is represented by particles collected from various natural sources: (a) Buffalo River, (b) Lake Ontario, (c) Lake Erie, (d) Lake LaSalle, and (e) Montmorillonite clay.

Fig. 8. Distribution of particle size for different environments. a) Measured, b) Calculated, c) Montmorillonite clay, d) Lake Ontario, e) Lake Erie, f) Lake LaSalle, and g) Buffalo River

Fig. 9. Distribution of particle size for different environments. a) Measured, b) Calculated, c) Montmorillonite clay, d) Lake Ontario, e) Lake Erie, f) Lake LaSalle, and g) Buffalo River

Fig. 10. Measured average settling velocity and calculated average settling velocity for different environments. a) Measured, b) Calculated, c) Montmorillonite clay, d) Lake Ontario, e) Lake Erie, f) Lake LaSalle, and g) Buffalo River

Conclusions

This study introduces the idea that the shape and surface properties of aggregates may be described by incorporating measured aggregate geometry, and fractal concepts to better characterize the impacts of aggregate shape in relation to traditional settling estimates that have assumed spherical aggregates. Measurements of settling velocities from natural aggregates collected from various environments may be predicted using existing methods of aggregate geometry and shape. This study explores the shape effect, as described by fractal geometry, is likely contributing to an increase in settling velocity with particle size. The areas measured using an in-situ imaging method and the calculated areas were found to be different and thus, it is difficult to analyze the behavior existing during settling. It is found that the settling velocity relative to Stokes’ law, decreases with increases in the particle size and with irregularities in the particle boundaries. Results from the present study support an understanding of the settling velocity by relating it to a fractal description of the aggregate shape and size in suspension and to the observed settling velocity of each particle with particle size for different natural suspensions.

Fractal dimension in 1-D (D1), 2-D (D2), and 3-D (D3). As a function of Perimeter (P), Area (A) and Volume (V), where \( \text{Fractal dimension} = \frac{\log P}{\log (P/A)} \) for 1-D, \( \frac{\log P}{\log (P/A)} \) for 2-D, and \( \frac{\log P}{\log (P/A)} \) for 3-D.