Image analysis to measure settling characteristics of granular sludge

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Introduction
Granule characteristics may change with time and growth conditions. It is important to monitor such changes, especially settling behavior to avoid biomass loss. The objective of this paper is to establish a method that uses microscopic image analysis as a tool to monitor morphology and use this to estimate settling velocity of granules.

Material and Methods
Five samples were used: two from industries and three from lab reactors (“Top”, “Middle”, “Bottom”). Images of at least 200 granules were taken using a stereomicroscope. Image processing was used to generate data about perimeter (P), area and shape factor (SF) of granules (equations 1–4). Equivalent diameter (De) of granules were calculated and used to estimate theoretical settling velocity of granules (Vt). A high-speed camera (50 fps) and a settling column were used to measure experimental settling velocity.

\[ D_e = \frac{P^2}{4\pi A} \quad (1) \]

\[ V_t = 0.781 f_w \left( \frac{D_e}{\delta_f} \right)^{0.714} \quad (2) \]

\[ SF = \frac{\sum_{i=1}^{N} A_i - \bar{A}_\text{mean}}{\sum_{i=1}^{N} A_i} \quad (3) \]

\[ \bar{A}_\text{mean} = \frac{1}{N} \sum_{i=1}^{N} A_i \quad (4) \]

\( f_w \) correction factor for wall effect
\( f_r \) rotation factor for fluid
\( \bar{A}_\text{mean} \) average area from centroid to perimeter

Result and discussions
All samples show different size distributions but similar pattern. Industry-2 and Top (from the lab reactor) have the most similar size distributions, while Industry-1 has much larger granules than the other samples.

Granule size increased from top to bottom in the lab scale reactor.

<table>
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<th>Sample</th>
<th>Value</th>
<th>Mean</th>
<th>Median</th>
<th>StDev</th>
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</table>

Table 1. Theoretical and experimental settling velocities and densities of granules.

Conclusions
Based on the above findings the following conclusions were made:
• Granules’ settling velocity depends on shape, in addition to size and density.
• A shape factor and equivalent diameter, both measured by analysis of images from a stereomicroscope, can be used to calculate settling velocities of granule samples comparable to measured velocities.
• This method can be an efficient way to monitor settling velocity variations.

References

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