Quantification of Sludge Morphology through the Aerobic Granulation Process

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Background

- Over 70% of water resource recovery facilities (WRRFs) use conventional activated sludge (CAS) to remove nutrients and carbon from wastewater (Figure 1).
- At times, CAS is dominated by filamentous bacteria resulting in slow settling sludge necessitating longer hydraulic residence times at WRRFs

Aerobic Granular Sludge (AGS)

- AGS is composed of large, dense, and spherical floc that allows rapid settling
- AGS requires complex operating parameters and tall reactors not common at WRRFs

Hydraulic Selection Technology

- Hydraulic selection is the process of selectively removing poor settling floc from the bioreactor through hydrodynamic forces.
- The hydraulic selector (Figure 2) develops a specific velocity gradient at its entrance to remove low density, poor settling floc.
- The hydraulic selector allows the development of AGS in standard WRRF reactors

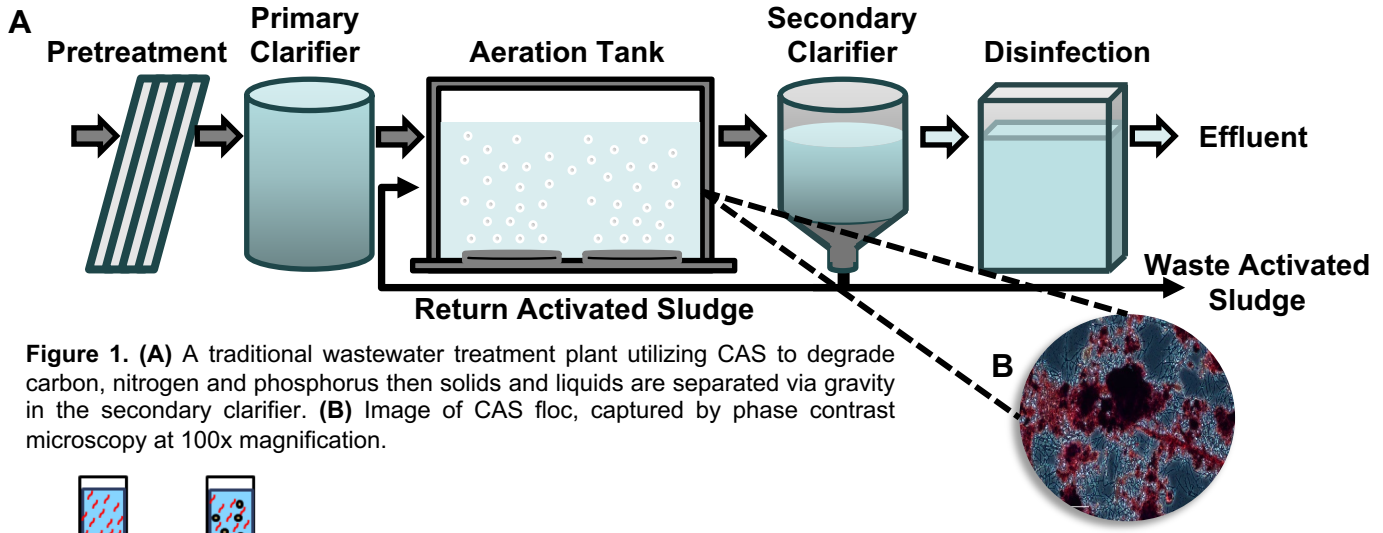

Figure 1. (A) A traditional wastewater treatment plant utilizing CAS to degrade carbon, nitrogen and phosphorus then solids and liquids are separated via gravity in the secondary clarifier. **(B)** Image of CAS floc, captured by phase contrast microscopy at 100x magnification.

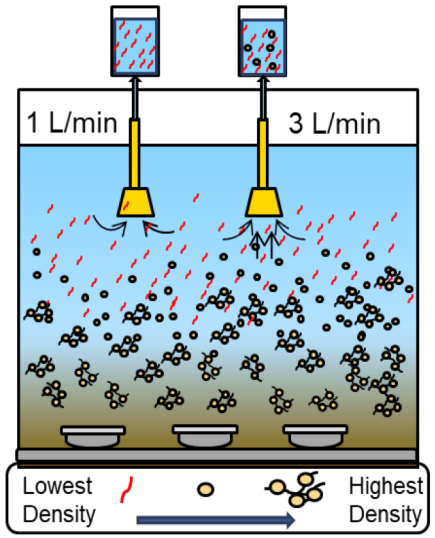

Figure 2. Schematic of hydraulic selector technology at different operating outflows.

Research Objectives

- Quantify the changes in activated sludge morphology of bioreactors with and without hydraulic selector technology
- Relate sludge morphology characteristics to sludge settling properties
- Rapidly and accurately evaluate hydraulic selector's performance

Approach

- Three pilot-scale 120 L bioreactors were operated at the Mines Park testbed for 80 days to evaluate different solid wasting mechanisms (Figure 3)
- Phase contrast images were captured weekly during the granulation process for each bioreactor under the microscope (Figure 4)
- Image analysis was performed to gain the following:
  - ***Filament abundance:*** the overall filament length compared to floc area
  - ***Aspect ratio (AR):*** describes how elongated the floc is
  - ***Floc diameter:*** the measure of the major axis, is related to floc density

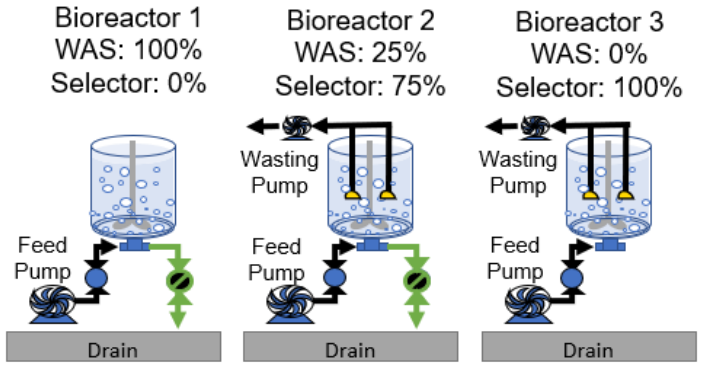

Figure 3. Schematic of pilot-scale system of the control bioreactor following traditional wasting mechanism (BR1), BR2 used a mix of hydraulic selector wasting and traditional wasting and BR3 wastes completely from the hydraulic selector.

Results

- In the first 35 days of the experiment, all three BRs observed a rapid reduction in relative filament abundance
- From day 21 to 59, the AR of BR1-3 did not greatly change (Figure 5A), however the mean floc diameter in Figure 5B shows an increase in floc size in BR2 and BR3
- By comparing AR and floc diameter, like in day 41, more insight can be gained

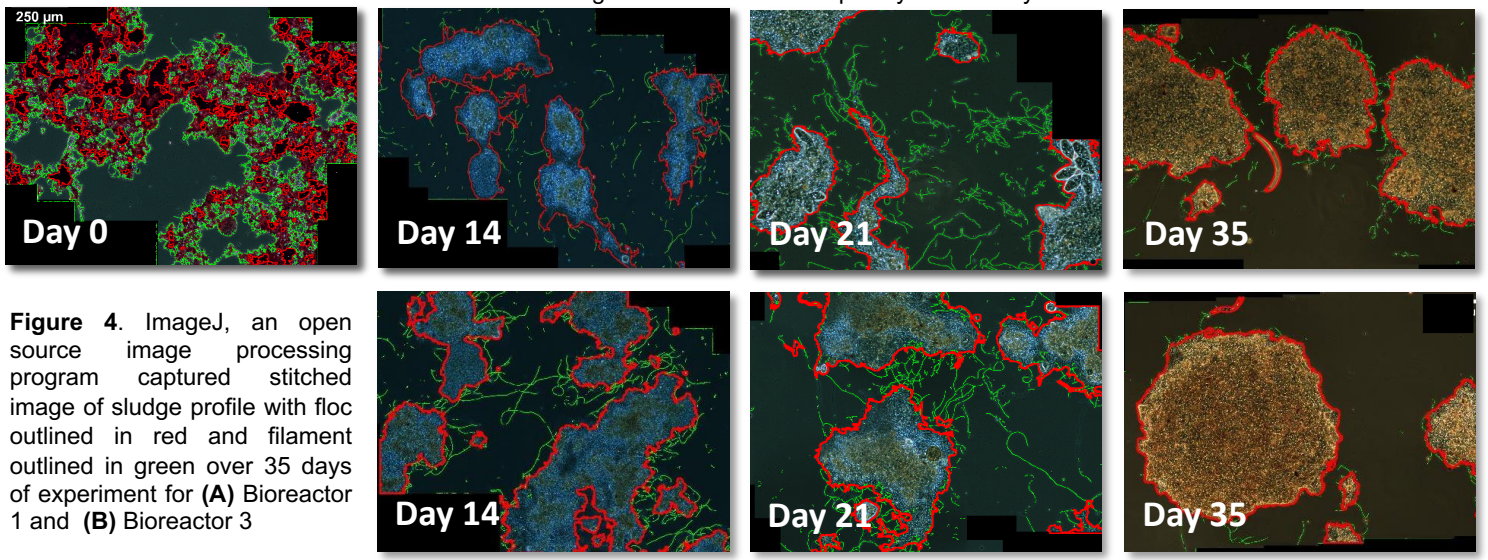

Figure 4. ImageJ, an open source image processing program captured stitched image of sludge profile with floc outlined in red and filament outlined in green over 35 days of experiment for **(A)** Bioreactor 1 and **(B)** Bioreactor 3

Concluding Remarks

- Phase contrast imaging with shape descriptors and floc diameter can be a viable tool to gauge sludge settling performance
- Increased quantity of images will be captured and analyzed to gain confidence in results
- Further investigation will allow relation of sludge morphology to operating conditions

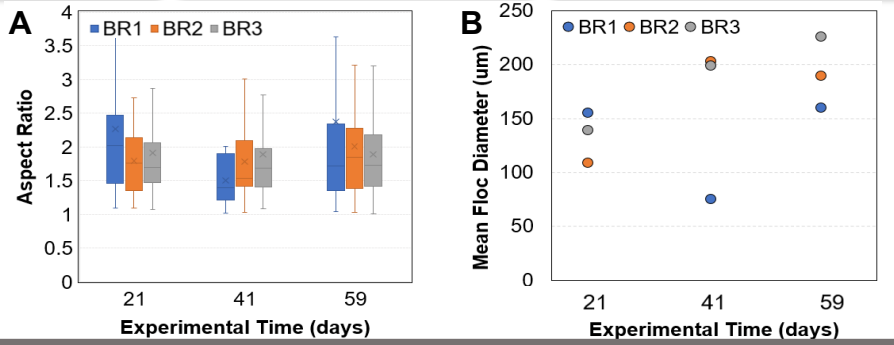

Figure 5. Captured at 40x magnification. **(A)** Shape descriptor, aspect ratio, over the experiment amongst all bioreactors. **(B)** Average floc diameter over the experiment amongst all bioreactors