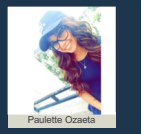
Hydraulic selector technology: improving the efficiency of conventional activated sludge

Energy and resource recovery



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Re-Inventing the Nation's Urban Water Infrastructure (ReNUWIt)

Background

CAS Treatment in Need of Reinvention

Due to urban population growth, there is increasing pressure on wastewater treatment plants (WWTPs) to expand plant capacity; however, WWTPs often do not have the option to expand due to infrastructural barriers such as the lack of space and the large expense of expanding systems. The EPA estimates that WWTPs will need more than $270 billion over the next 20 years to meet the demand of an additional 56 million users. Therefore, innovation is needed to make treatment processes more efficient.

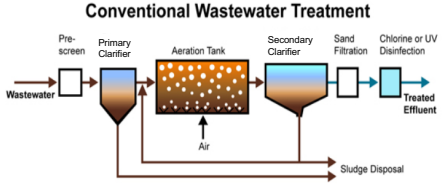

Figure 1. Conventional activated sludge treatment system. Primary and secondary clarifiers use gravity separation to remove inert and biological.

Hydraulic Selection Development

Hydraulic selection technology has been developed at Colorado School of Mines as a potential solution for sludge with poor settling characteristics. Hydraulic selection is a technology that uses hydrodynamic forces that are created by a vacuum and specially designed selector placed inside a secondary clarifier or activated sludge basin. Poor settling solids are passively removed by the selector from the activated sludge enhancing the settling characteristics of the remaining sludge.

Research Hypotheses and Objectives

H1: If hydraulic selection technology is implemented in a bioreactor, then it will remove poor settling floc containing high concentrations of filamentous bacteria.

O1.1: Identify and quantify filamentous bacteria that are removed by the hydraulic selector

H2: The settling velocity of activated sludge floc in an SBR equipped with a hydraulic selector will be higher compared to a conventional batch reactor.

O2.1: Measure sludge volume index (SVI) and settling velocity of BR1 and BR2 three times a week.

Approach

Wet Chemistry Analysis

In a 1 liter beaker, activated sludge from BR1 and BR2 are sampled. Settling velocity is measured every two minutes for ten minutes and once more after 30 minutes for the sludge volume index (SVI_{30}), Equation 1.

$$Eq\ 1. \quad SVI_{30} = \frac{Settled\ Sludge\ Volume\ (mL/L)}{Total\ Suspended\ Solids\ (g/L)}$$

Approach Cont.

Biological Analysis

Weekly activated sludge phase contrast photos were taken. Biological samples were also frozen for future DNA analysis and filamentous quantification by real-time polymerase chain reaction.

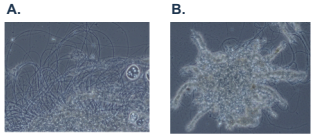

Figure 2. Activated sludge phase contrast pictures. A) BR1, March 3, 2018 (T28) at 40X. B) BR2, March 3, 2018 (T28) at 40X

Pilot Model Construction

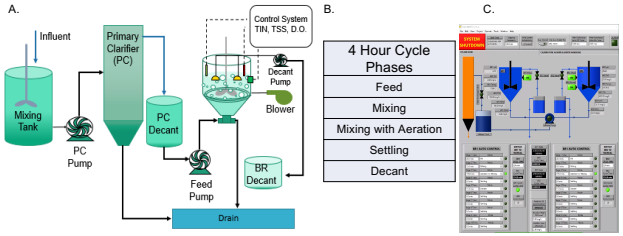

Figure 3. A) Pilot scale configuration with one 30-gallon bioreactors fed from the primary clarifier (PC) decant; B) The bioreactors operated on a 4 hour cycle comprised of 5 phases. C) An automated system was designed in LabView and connected to sensors to provide continuous information about the system.

Results

Settling Velocity

Hydraulic selection proved to be successful. The rate at which solids settle over a period 4 minutes slowly increased by 18% over an 80 day period, Figure 3. Both bioreactors had a similar trend for the first 30 days, after this period BR2 begins to outperform BR1. Both bioreactors operated on identical cycles with the exception of BR2 using the hydraulic selector to decant comparted to BR1 which used a weir.

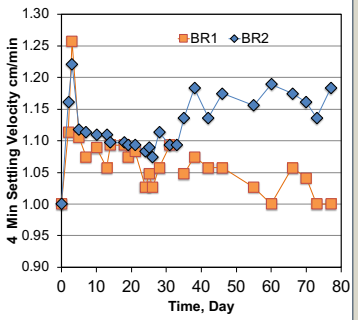

Figure 4. 4 minute settling velocity of BR1 and BR 2, settling velocity was measured in a 1-L beaker

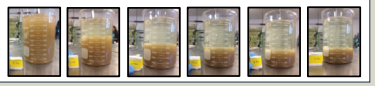

Figure 5. Pictures of activated sludge after 30 minutes of settling. Rapid sludge transformation occurs within first three samples.

Sludge Volume Index (SVI)

The SVI of a WWTP is highly variable due to changing influent volumes of water, carbon and nutrient concentrations entering the facility and their impacts on filamentous growth. At Mines Park these variations are magnified due to its small water shed. Most activated sludge plants produce high-quality effluent when the SVI is in the range of 100 to 200 mL/g. An SVI above 250 mL/g, contains sludge that settles slowly and compacts poorly.

The SVI of both BRs begins at 340 mL/g (Fig 6). Both bioreactors experience an initial decrease in SVI, but within a month BR1's SVI slowly increases back to the 340 range, the following month solids begin to washout of BR1 leading to high SVI values. BR2 maintains an SVI right below 200 mL/g for the entire duration of the experiment. An 18% increase in 4 minute AS settling results in a drastic difference between the initial SVI_{30} to the stable SVI_{30} (Fig. 7A and 7B).

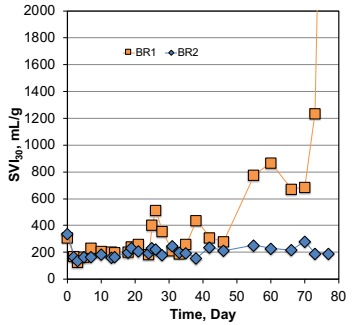

Figure 6. Sludge Volume Index (SVI) of BR1 and BR2 over an 80 day period. BR1 operates without and BR2 operates with hydraulic selector technology.

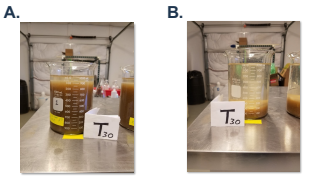

Figure 7. Activated sludge from BR2. A) Activated sludge before hydraulic selector implementation. B) Activated sludge after the implementation of hydraulic selector

Conclusions

- Hydraulic selection technology has lead to the development of fast settling sludge in a batch reactor
- Phase contrast photos indicated that improved settling was a result of decreased filamentous bacteria in the activated sludge

Next Steps

- Continue to collect data from BR1 and BR2 to study long term performance of hydraulic selector and optimum selection parameters
- Validate CFD models with bench scale experiments
- With the use of Quantitative Polymerase Chain Reactions, filament bacteria will be tracked to record the concentrations throughout pilot scale experiments

Acknowledgements

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