Determining Effects of Class I Landfill Leachate on Biological Nutrient Removal in Wastewater Treatment

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Abstract

Leachate management challenges at wastewater treatment plants (WWTPs) vary by POTW size, percent of leachate to overall flow, leachate composition, waste composition, and regional differences, and are known to commonly include ammonia removal inhibition and biological treatment upset. Both of these issues can be seen in the activated sludge process of the treatment train during biological nutrient removal and can be affected by compounds in the leachate matrix. As wastewater treatment operators are increasingly refusing to accept landfill leachate, the overall goal of the research is to determine the effect of landfill leachate on nitrifying activated sludge activity and determine if activated sludge can be adapted to handle leachate loadings that are known to cause overloading. This study gauges the specific impacts of leachate on biological wastewater treatment and provides data that could allow WWTPs to decrease biological treatment disruptions and ammonia removal inhibition that occur as a result of leachate management.

Objectives

Objective 1: To quantify the effect of various landfill leachate sources on nitrifying activated sludge utilizing Specific Oxygen Uptake Rate (SOUR).

Objective 2: Evaluate the effect of leachate on the efficacy of biological nutrient removal (BNR) activated sludge processing using lab scale sequencing batch reactors (SBRs).

Objective 3: Determine the extent that BNR activated sludge can be adapted to effectively handle a loading of landfill leachate known to cause overloading using lab scale sequencing batch reactors (SBRs).

Approach

Phase I. All reactors receive synthetic wastewater.
Phase II. Reactors receive defined ratios of synthetic wastewater and landfill leachate until steady state is achieved.
Phase III. All reactors receive an organic over-loading of landfill leachate (30% v/v).

Acknowledgements

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References

Arnaout, C., and Gunsch, C., 2014. Assessing the Effects of Silver Nanoparticles on Biological Nutrient Removal in Bench-Scale Activated Sludge Sequencing Batch Reactors. Environmental Science and Technology 40: 970 – 976.

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Results

Results indicate that BNR activated sludge may be able to be adapted to handle higher loads of landfill leachate in terms of COD removal and TIN removal than BNR activated sludge that has never been exposed to leachate.

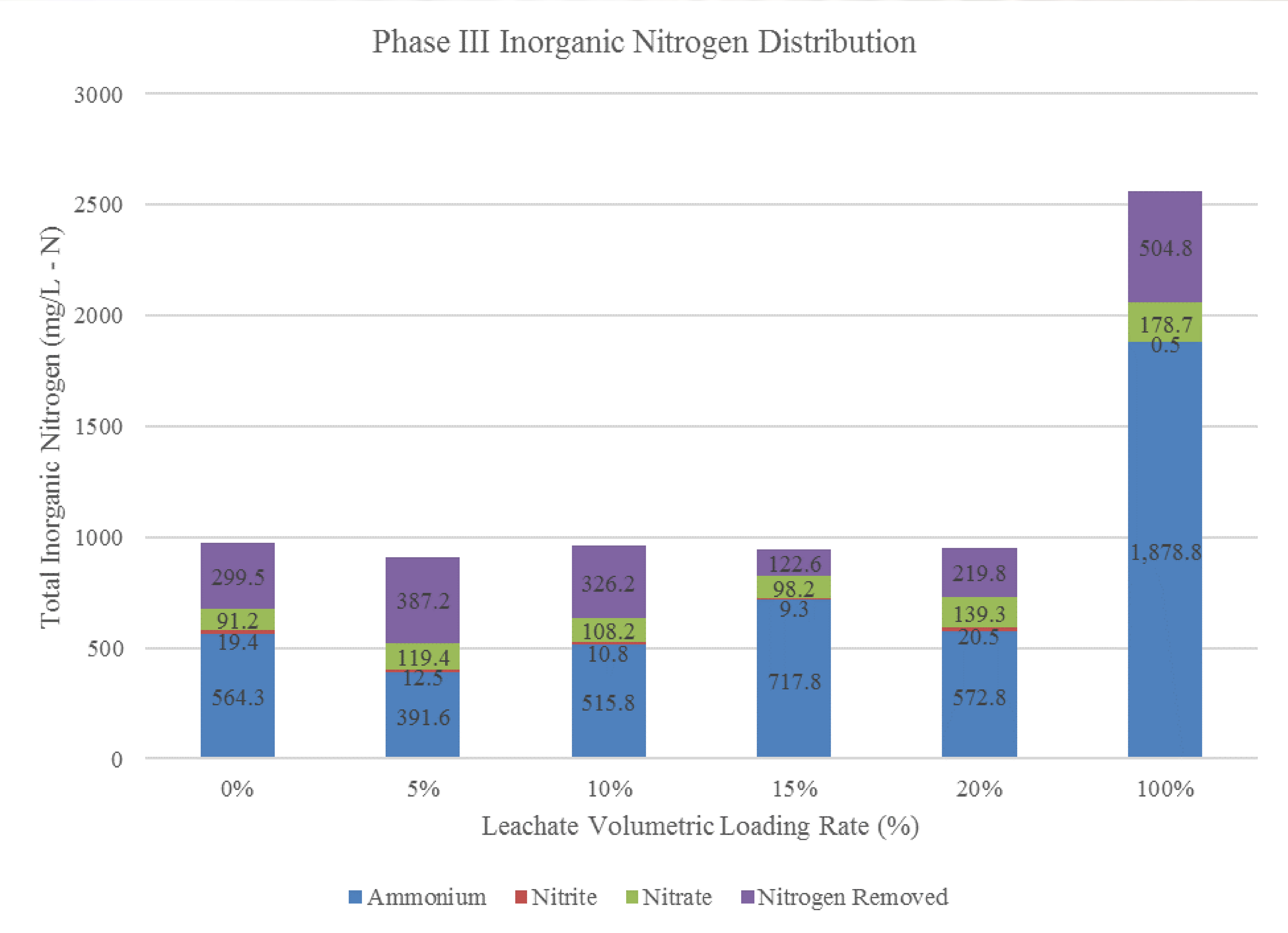

Figure 4. These observations suggest that SBRs adapted to a 5% and 10% leachate loading in Phase II accomplished nitritation (first step of nitrification where ammonium is converted to nitrite) more effectively than the control in Phase III which could suggest previous exposure to leachate allowed the microorganisms to adapt to the components of the leachate that may have otherwise decreased nitritation efficacy as seen in the control. There appears to be inhibition in nitratation (second step of nitrification where nitrite is converted to nitrate), as indicated by the small accumulation of nitrite in reactors exposed to 0% leachate and 20% leachate in Phase II. There are several reasons for observed inhibition in leachate loadings over 10%, including unfavorable C:N ratios, leachate toxicity, and elevated free ammonia levels (Brennan et al, 2017). All reactors appear to have accomplished denitrification at similar levels, indicated by the nitrate concentrations in the effluent.

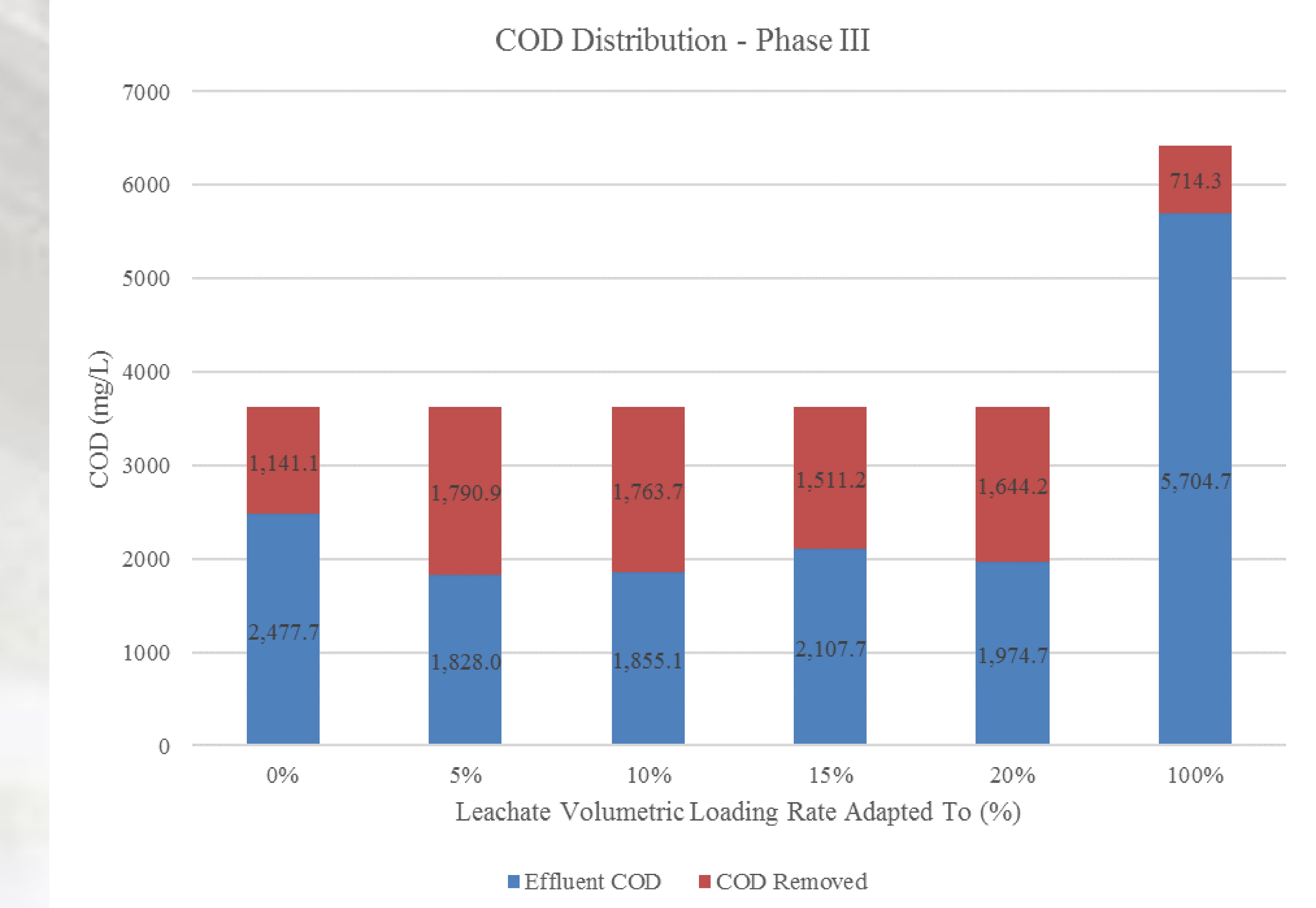

Figure 5. SBRs previously exposed to leachate loadings had a higher removal of COD that the SBRs never exposed to leachate (Figure 8). The SBRs exposed to 5% and 10% leachate loading exhibited the highest amount of COD removal while the SBRs adapted to a 15% and 20% leachate loading exhibited slightly lower amounts of COD removal compared to the reactors adapted to 5% and 10% leachate loading.

Methods and Materials

The construction, operation, and leachate loading tests are conducted based on previously published work (Arnaout et al., 2014). Twelve 8-L bench scale SBRs are constructed out of square pieces of plexiglass (8 x 8 x 8 in, 1/8 in. thick) and welded together using poly(methyl methacrylate) (Figure 1 – 3). A solid retention time of approximately 14 d is utilized to ensure optimal conditions for nitrification and a hydraulic retention time of 5 h is used in order to fall within the typical range for contact stabilization systems. An operating cycle of 8 hours is achieved and upon reaching steady state removal of nitrogen and chemical oxygen demand, leachate was added into stock concentration either directly to the reactors (for pulse additions) or into the influent medium (for continuous additions) (See figure 2). Phase I, II, and III are described in Approach. After steady state was achieved, all reactors were charged with a 30% leachate v/v loading for one week to determine COD and nitrogen removal (Phase III), which corresponded to an organic loading rate of 3.6 g COD / (L d).

Figure 1. Photo of reactor setup. Each reactor contains nitrifying activated sludge.

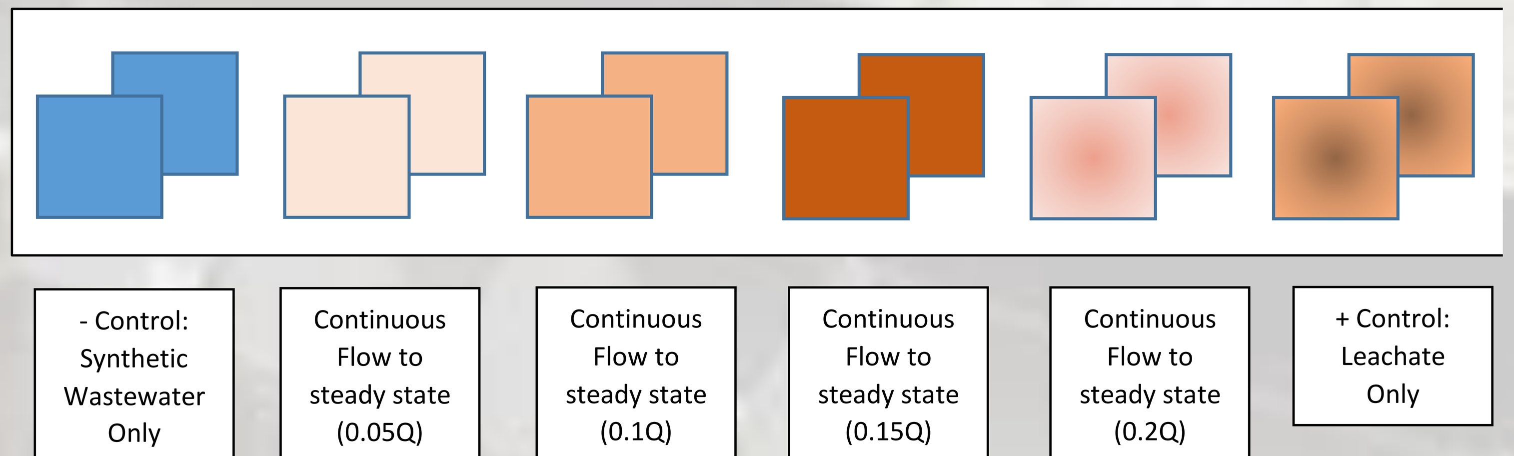

Figure 2. Layout of reactor conditions. Six conditions are operated in duplicate. The negative control receives only synthetic wastewater, the positive control receives only leachate. The two continuous flow reactors receive low and high volumes of leachate, respectively, to mimic real-world conditions where leachate continuously enters the wastewater system. The pulse fed reactors periodically receive leachate in addition to the synthetic wastewater to mimic real-world conditions where leachate may enter the system via pulse input.

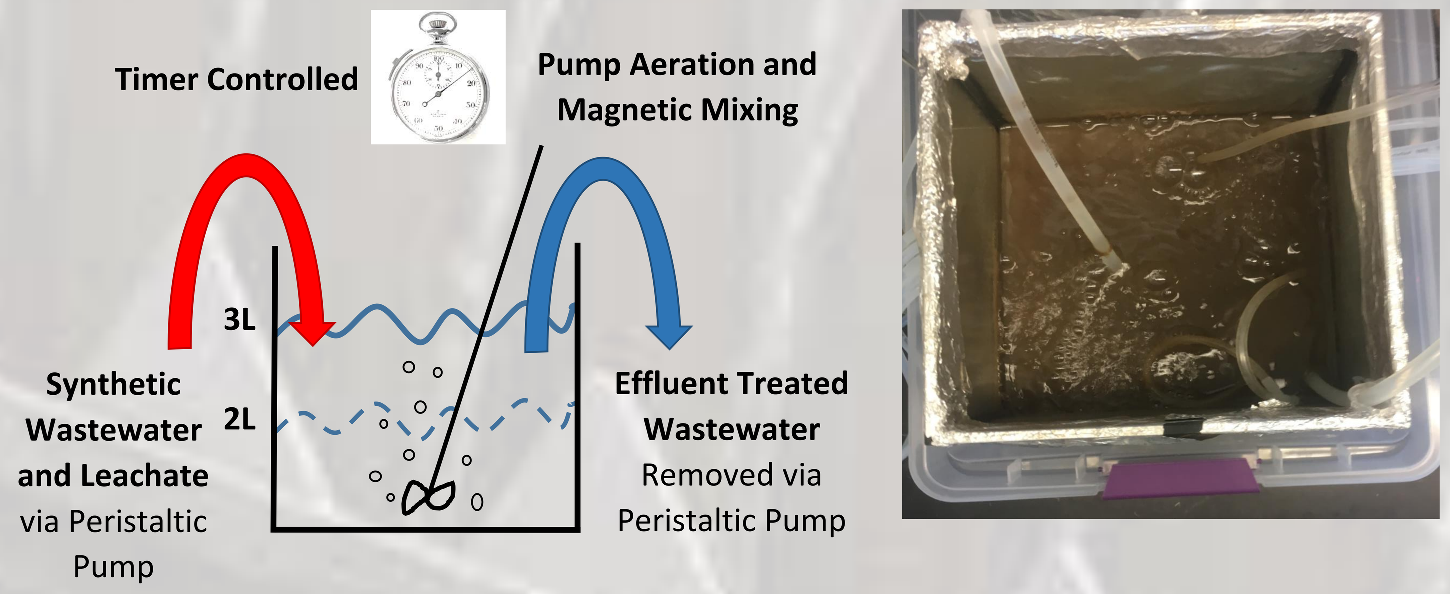

Figure 3. SBRs are operated with timers, peristaltic pumps, stir plates and aerators. Peak volume achieved in all reactors is 3.0 L and the volume after decanting is 2.0 L. SBRs are operated on an 8 h cycle, beginning with 3 minutes of influent synthetic wastewater feeding, 3 hours of aerating and vigorous mixing, 3.3 h of mixing only, 1 h of settling, 3 min of decanting, and 30 min idle.