Quantifying Dissolved Methane in Anaerobic Baffled Reactor Effluent and Determining the Impact of the Grease Layer

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Water scarcity is a growing issue in the United States, forcing scientists and engineers to find ways to reduce water usage and reuse wastewater. Unfortunately, the aerobic treatment process for reclaimed water can be costly and require a significant amount of energy and oxygen. Treating this water anaerobically instead would turn it into an energy resource, reducing costs by eliminating both energy and oxygen input.

Energy in wastewater exists in the form of microbial organics which, when treated anaerobically, are converted to volatile acids, then acetate, and finally methane gas which can be burned as fuel. This energy can be used to power the treatment process, allowing for energy-neutral wastewater treatment or even energy-positive wastewater treatment, in which surplus energy is returned to the grid. Not only does this process eliminate the costly need for energy, it also eliminates the cost of expensive oxygen, required for traditional aerobic treatment, and decreases the biomass output.

In order for this treatment to be feasible, existing wastewater treatment plants must be modified to include the anaerobic process. An anaerobic baffled reactor (ABR) is a potentially effective way to do this. The ABR is a series of cells through which wastewater travels based on upflow and downflow conditions. This allows for minimum energy input requirement and enhances biomass contact within the reactor, effectively treating the influent.

The pilot ABR at Plum Creek Water Reclamation Authority consists of four sequential cells. Influent wastewater first flows down through pipes and then up through the biomass blanket. The majority of the dissolved gases in the liquid water, primarily methane and carbon dioxide, off-gas to the headspace of the reactor where they can be collected for sampling and, in practice, for use as energy. However, it is suspected that more of the methane is remaining dissolved in the liquid phase than expected based on Henry's constant. This could be because either because the methane does not have time to come to equilibrium within the reactor or because the grease layer, which separates the liquid and gas phase within each cell and builds up over time, causes a larger amount of the gas to remain dissolved. It is important to quantify this dissolved methane because methane is a potent greenhouse gas.

The pilot reactor first went online on June 19, 2012. After running for a full year, core samples were collected and the grease layer was removed on June 20, 2013. While the grease does start to quickly build up again after the removal, a significant amount of time will pass before it reaches a distance similar to that prior to the cleaning. Both liquid and gas samples from the reactor were collected before and after this cleaning to determine the effect of the grease layer on the dissolved methane content of the partially treated wastewater, with the expectation that the dissolved methane quantity would be lower after the cleaning, or that more of the methane would exist in the headspace.

Serum bottles were used to collect about a 50 mL aliquot of liquid from two ports, a low port and a high port, located on the front of each of the four cells. After collection, the bottles were capped and sealed immediately. 2.5 mL of headspace gas from each cell was collected and injected into nitrogen purged serum bottles. These samples were then refrigerated in a 4°C cold room for approximately 24 hours. Then, the samples were removed from the cold room and brought to room temperature in preparation for gas chromatography analysis. The liquid samples were shaken before sampling to facilitate establishment of equilibrium.

Gas chromatography analysis and calculations revealed that the grease layer has no significant impact on the dissolved methane quantity (See Figures 1 and 2). However, comparison of expected aqueous concentrations, calculated from the measured headspace concentration using Henry's constant, and the measured liquid concentrations reveal that the aqueous phase in cell 4 is supersaturated with methane (Figure 2). This is true both before and after the reactor cleaning. The value used for Henry's constant was confirmed by testing deionized water samples injected with known amounts of methane gas. The measured headspace concentrations were compared to the expected headspace concentrations and found to be very similar, thus confirming Henry's constant. Likely, the liquid and gas phases do not have time to come to equilibrium within the reactor.

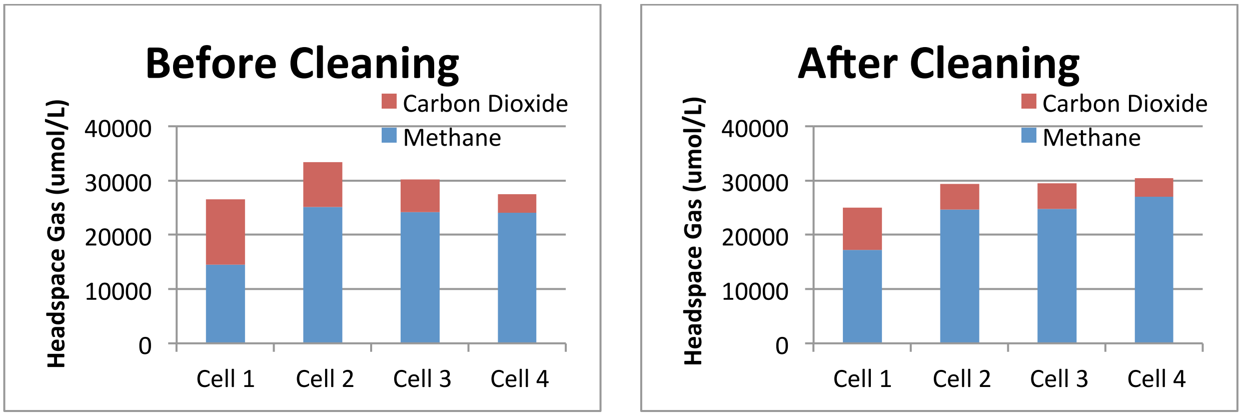

Figure 1: Reactor headspace concentration of gases before and after cleaning.

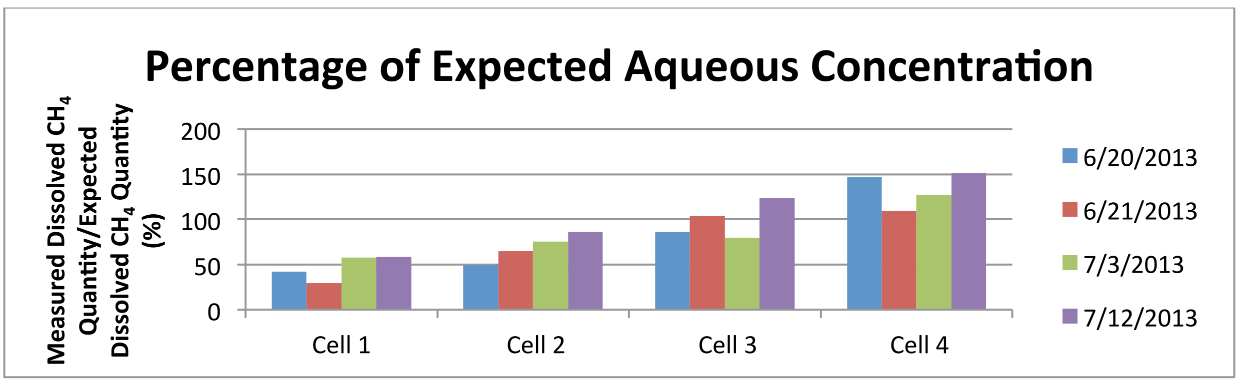

Figure 2: Percentage of measured dissolved methane out of the expected quantity.

In order to test this theory, time analysis tests were conducted. Additionally, some samples were collected and immediately treated with 2-bromoethane sulfonic acid (BESA) in varying concentrations in order to inhibit any further methane evolution occurring after collection. Collected in the same manner as described above, these samples were analyzed by gas chromatograph immediately following sample collection, one day after collection, and four days after collection. Results proved inconclusive with little change visible, likely due to gas leakage. Furthermore, due to time and material limitations, no liquid samples were collected in an anaerobic manner and methane gas was presumably lost during the collection process.

Overall, the experiments indicate that the grease layer has no impact on the equilibration of methane and carbon dioxide in the reactor. Results also confirm that cell 4 of the reactor is supersaturated with methane, probably because the gas does not have time to come to equilibrium within the reactor. Further time analysis could confirm this hypothesis. Future work using an anaerobic liquid sample collection method would also benefit this research.