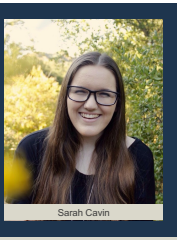
Zeolite-anammox bioreactor

Energy and resource recovery

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

Sarah Cavin, Jennifer Lawrence, Lisa Alvarez-Cohen
University of California, Berkeley


Sarah Cavin

Background

Topic:
- Anaerobic ammonium oxidation (anammox) is a biological process that offers an energy-efficient pathway to treat wastewater by removing nitrogenous compounds from wastewater effluent

Process:
- Anammox bacteria convert ammonium to nitrogen gas using the following reaction:

$$NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O$$

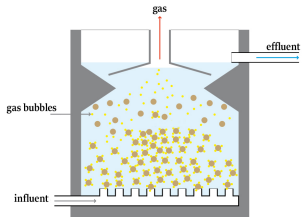
Advantages:
- This process is both energy-efficient and cost-efficient and reduces greenhouse gas production as compared to conventional methods for nitrogen removal

Issue:
- The bacterial doubling time can be between 10 and 28 days, resulting in slow start-up times and difficulty maintaining enough biomass for effective treatment

Proposed Solution:
- Using a natural zeolite growth support media for bacteria to attach to could increase retention of biomass and decrease process start-up times

Approach

Using two vertical upflow reactors with a constant inflow of nitrogen gas and synthetic wastewater, the hypothesis that zeolite would decrease start-up times was tested using one reactor containing only anammox bacteria and one with zeolite along with the anammox bacteria.



Synthetic wastewater influent was prepared using:
- Concentrated salts solution (NaCl, KCl, $MgCl_2$, $CaCl_2$)
- Solution of eight trace elements
- Trace amounts of $FeCl_2$ in HCl
- Potassium Phosphate
- Sodium Bicarbonate
- Ammonium Sulfate
- Sodium nitrate

The compounds were dissolved in DI water while maintaining anaerobic conditions by bubbling nitrogen gas through the media and brought to a pH of 6.8

Samples were taken at various time intervals from both reactors and the concentrations of ammonia, nitrate, and nitrite present were measured to analyze the performance of anammox as compared to anammox with zeolite.

Additionally, bacterial samples were taken from both reactors at various time intervals and DNA was extracted in order to perform qPCR to determine quantities of anammox bacteria along with total bacterial colonies.

Results

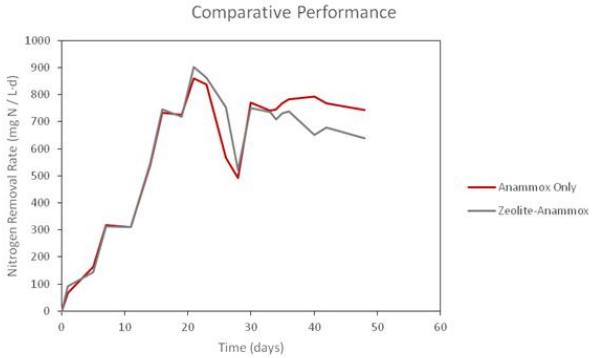
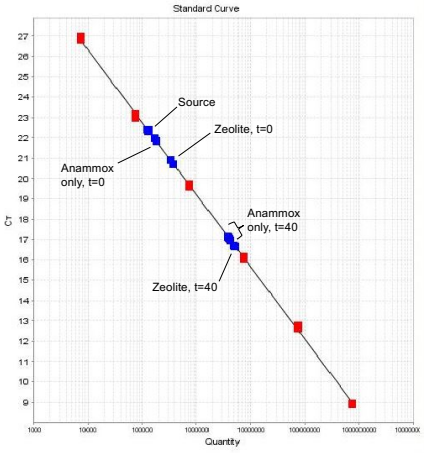


Figure 1: Comparative nitrogen removal rates over time

As shown in Figure 1 above, when concentrations of ammonium, nitrate, and nitrite were measured from samples taken from both reactors over the span of 50 days, the rate of nitrogen removal of both reactors was comparable. The rates of removal within the first 10 days were almost exactly the same.



Target: HzsB Slope: -3.555 Y-Inter: 40.537 R^2: 1 Eff%: 91.125

Figure 2: qPCR results of samples from both reactors

Figure 2, shown to the left, displays the qPCR results for anammox bacteria sampled from the source bacteria, the two reactors at initial start-up (time = 0), and the two reactors at time = 40 days.

The red points signify points on the standard curve and the blue show results from the sample testing. The results show that the reactor containing zeolite had slightly higher amounts of anammox bacteria as compared to the reactor with no zeolite, though the relative amounts were within the same order of magnitude as each other.

The overall bacterial colonies were tested as well and it was determined that the anammox bacteria was increasing at a higher rate than the overall bacteria, so the increase in anammox bacteria over time is not simply due to an overall increase in total bacteria.

Conclusions

The results of this research show that there is no evidence to conclude that the zeolite tested helps improve start-up times or overall performance and efficiency of the reactors.

Though the qPCR results show a slight increase in the amount of anammox bacteria present in the zeolite reactor as compared to the reactor without zeolite, the difference is not significant enough to result in an increased rate of nitrogen removal.

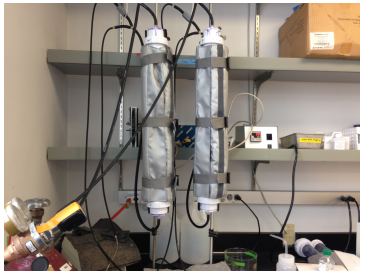
Next Steps

In future experimentation, we plan to track and interpret changes in the microbial community in the reactors during start-up phases, looking into relative abundance and functional capacity for different reactor configurations (continuous flow with membrane to contain biomass versus upflow reactors with anammox and zeolite-anammox). This would be done using DNA extraction, qPCR, and fluorescence in-situ hybridization (FISH).

We also plan to test the tolerance and response of the microbial community to stress in the form of nitrite concentrations. This would require running multiple batch experiments with varying concentrations of nitrite present and analyzing the bacterial abundance from each batch at various time intervals.

Reference Images


Stock anammox bacteria


Upflow reactors set-up

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