Application of Zeolites with Anammox for Nitrogen Removal

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Introduction: Since the start of the twentieth century, there has been an increasing amount of excess nitrogen in water bodies as a result of needing to meet the food demands of an increasing world population. As a result of this, the Haber-Bosch process practically doubled the global rate of nitrogen gas transformation into reactive nitrogen.[1] Due to nitrogen generally being a limiting nutrient, the excessive release of reactive nitrogen into the environment has caused eutrophication in aquatic ecosystems and acidification in freshwater systems.[2] Major sources of inorganic nitrogen in the aquatic environment include agriculture, fossil fuels, and wastewater effluent.[3] The aim of this research study is to investigate a novel method to enhance the removal of nitrogen in wastewater treatment facilities by using anaerobic ammonium oxidation (anammox), as a biological wastewater treatment process.

Unlike the conventional nitrification and denitrification processes, anammox uses nitrite as an electron acceptor to directly convert ammonium into nitrogen gas in the absence of oxygen (Figure 1).[4] With a lower aeration requirement and no organic carbon supplement, wastewater treatment facilities have begun to operate full-scale anammox reactors for the remediation of ammonium-rich wastewater effluent.[5] Although the anammox process is cost-effective and consumes less energy, the bacteria responsible for anammox are strictly anoxic autotrophic organisms with very slow growth rates and long start-up times.[6] Therefore, a better understanding of the anammox process and its bacteria's growth is necessary.

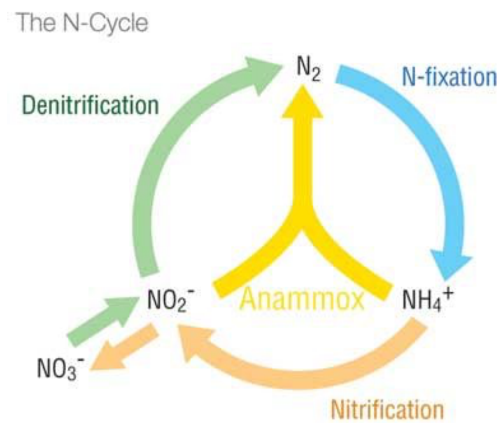

Figure 1: Nitrogen Cycle
Cited from: Water World

The research objective for this study was to identify the impact zeolites have to enhance the retention of biomass within an anammox reactor to decrease its required process start-up time and enhance nitrogen removal. Clinoptilolite zeolites are hydrated aluminosilicate minerals of a porous structure with a high sorption affinity for ammonium and are capable of ion exchange.[7] Because zeolites have previously been used as an adsorbent in wastewater treatment, they could potentially be used to sorb the ammonium within anammox bacteria and stabilize its growth.

Methods: Start-up experiments were conducted in two, side-by-side one-liter upflow anaerobic sludge blanket (UASB) reactors. Each reactor contained 1 g VSS/L anammox biomass, while 10 g/L of crushed clinoptilolite zeolites was added to only one reactor. The influent batch solutions for each reactor were created with different amounts of ammonium (NH_4^+) and nitrite (NO_2^-) that were determined by how low the effluent concentrations were reaching in order to stabilize performance. Effluent samples for ammonia (NH_3), nitrite (NO_2^-), and nitrate (NO_3^-) were measured frequently through spectrophotometric analysis using a HACH instrument. To characterize the potential utility of clinoptilolite zeolite within anammox enrichments, these measurements were used to calculate the nitrogen removal rates (NRR) over an approximate 50-

day period. In addition, pairs of control (anammox only) and experimental zeolite isotherm bottles were set up with different concentrations of NH_3 ranging from 0 N g/L to 50 N g/L. After an incubation period, appropriate dilutions were performed and an ion analysis was conducted using an ion chromatography (IC) machine. This analysis was used to identify the changes in zeolite sorption capacity with the ammonium within anammox bacteria.

Results: The major outcomes of this research stem from the NRR results from the UASB reactors, as well as the ammonium sorption curves. As shown in Figure 2, the NRR for both reactors are quite variable. However, an important detail to highlight is that in the zeolite-anammox reactor, the zeolites are shown to have an effect on the metabolism for nitrite since the effluent values are not as consistent as the anammox-only reactor. Therefore, more extensive research is required to understand the interactions of zeolite with these nutrients in solution.

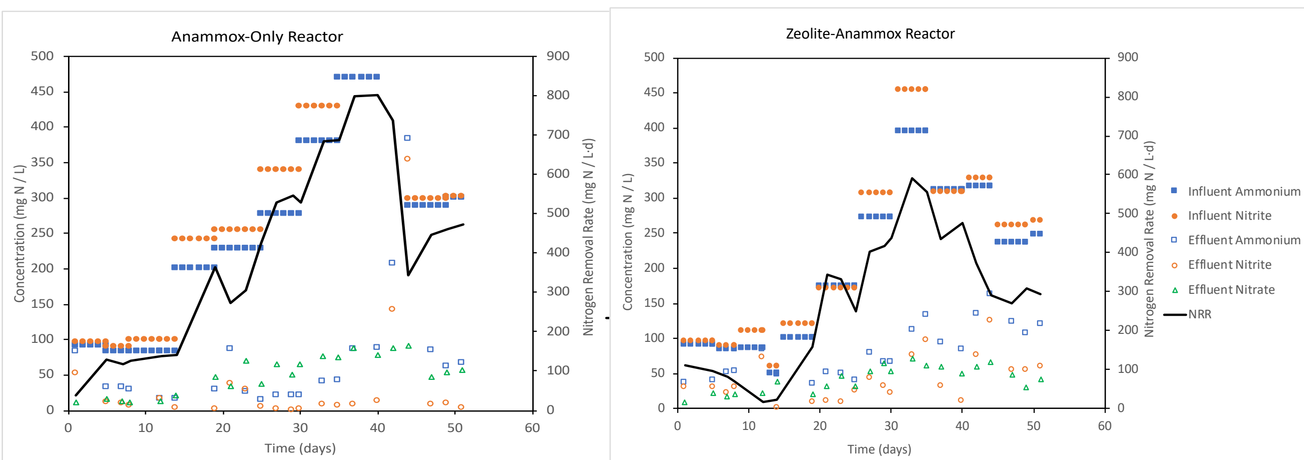

Figure 2: Nitrogen Removal Rates

Furthermore, ion analyses suggested that zeolites were capable of sorbing ammonium, but due to the conditions on incubation, the results may suggest otherwise. As shown in figure 3, it may appear that zeolites are releasing aqueous ammonium, but in reality the aqueous ammonium may have been converted to ammonia gas during the incubation period. Since samples were done in triplicates and confidence testing was performed to troubleshoot this, our methodology was consistent despite reaching a one to one ratio.

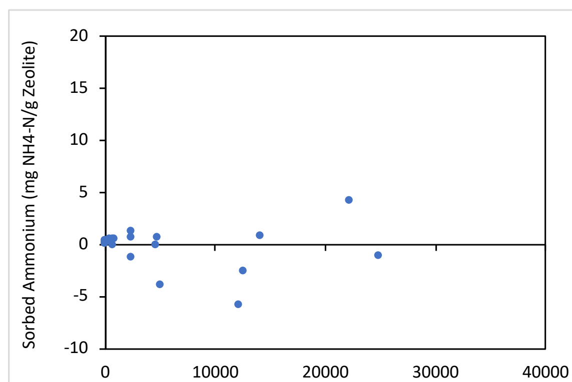

Figure 3: Ammonium Sorption Curve

Conclusion: As a result, zeolites impact on anammox may improve the start-up phase for nitrogen removal, but more research is needed to fully confirm this. The amount of time it took for these anammox full scale reactors to reach a NRR of 1 g/L/day was about 50 days under these experimental conditions. Furthermore, the addition of zeolites may have enhanced biomass retention, but not as much as we expected possibly due to being washed out of the reactors or other factors, but future research will investigate this.

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