Nitrogen as ammonia removal efficiency at the City of Wyoming clean water plant.

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Abstract

Nitrogen and phosphorus are two of the most significant pollutants on Earth, causing hypoxia and eutrophication in aquatic environments if not removed. These contaminants originate from anthropocentric sources and much of it flows through our municipal sanitary systems into the natural environment. This internship and study investigates the efficiency of biological nutrient removal (BNR) at the city of Wyoming's clean water plant with a primary focus on nitrogen as ammonia removal. BNR is the primary nutrient removal process as it breaks down ammonia into nitrogen. The internship was conducted as an operator within the plant and consisted of routine sampling and laboratory analysis for a three-month period. These skills assisted in the advancement of BNR knowledge in preparation for the state of Michigan's Class B license for wastewater treatment that will occur in the fall of 2025. The scope of this project was broken down into three parts: ammonia profiling and efficiency removal in the facility's three aeration basins, sampling and testing of volatile fatty acid (VFA) acidogenesis in the four primary clarifiers and investigation into the facilities long-time issue with nitrate residual in the effluent flow due to incomplete denitrification in the

anoxic zone. The samples were analyzed in collaboration with both clean water and drinking water laboratory staff. The results were that although the BNR efficiencies were high, the nitrate residual could be the result of several factors, which are discussed. A potential solution explored is carbon augmentation in the anoxic zones to supplement varying levels of VFA acidogenesis, additional testing for acidogenesis, alternate VFA fermentation methods and inclusion of a constructed wetland.

Two common environmental anthropogenic pollutants on Earth are nitrogen and phosphorus. A significant point source for these contaminants is the discharge of wastewater from residential and industrial wastes from municipal wastewater treatment facilities. If left untreated, these contaminants can infiltrate aquatic environments, causing hypoxia and eutrophication. These wastes are treated at municipal wastewater treatment facilities using a variety of treatment methods. An increasingly popular and cost-effective method of removing these contaminants is by biological nutrient removal (BNR), a process in which certain environmental conditions are created to promote growth of a certain trophic level of bacteria. These bacteria break down ammonia and phosphates into elemental form and eliminate their danger as pollutants. This treatment method requires complex and routine laboratory testing and extensive operator training to maintain these optimal environmental conditions. A critical step to the successful removal of nitrate is the denitrification process completed by heterotrophic anaerobic bacteria. Being heterotrophic, these bacteria require external carbon sources. The plant currently ferments acetic acid in the primary clarifiers to be used as the main carbon source for these bacteria. Despite data showing fermentation, there is still a nitrate residual in the plants effluent. This raises the research question:

Is there a correlation between the acidogenic fermentation and incomplete denitrification?

The materials and methods include VFA sampling each of the plants four primary clarifiers for a total of 37 samples through the testing period of May 20th to August 30th. These samples were filtered using .2 micron filters and sent to the drinking water plant in Holland, MI to be tested using flame ionization detection on gas chromatography. Ammonia sample swerve taken from each of the aeration basins cell 1 and 2, for a total of 222 samples taken. These samples were tested using a HACH DR 6000 colorimeter. Nitrate and nitrite samples were taken twice a week by the operations staff and tested by the laboratory techs using standard EPA methods.

The results for VFA showed an overwhelming percentage of VFAs fermented as acetic acid. Figure 1 shows that acetic acid is the most fermented acid at 83%. Figure 2 shows the ammonia removal efficiency for the clean water plant. Testing showed a 99.5% ammonia removal rate, a 99.8% nitrite removal rate but only a 37% nitrate removal rate. This suggests incomplete nitrification in the anoxic zones. The acetic acid fermentation experienced growth and crash cycles through the testing period, showing results as low as 0 mg/l

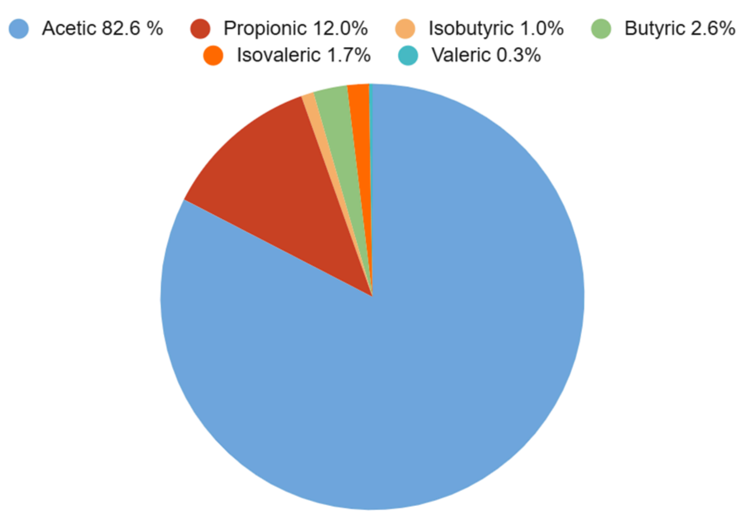

Figure 1: pie chart showing acidogenic fermentation results by acid

and as high as 156 mg/l. This suggests that the lack of carbon source is not the primary issue for the incomplete denitrification. Figure 3 shows the acidic acid levels alongside

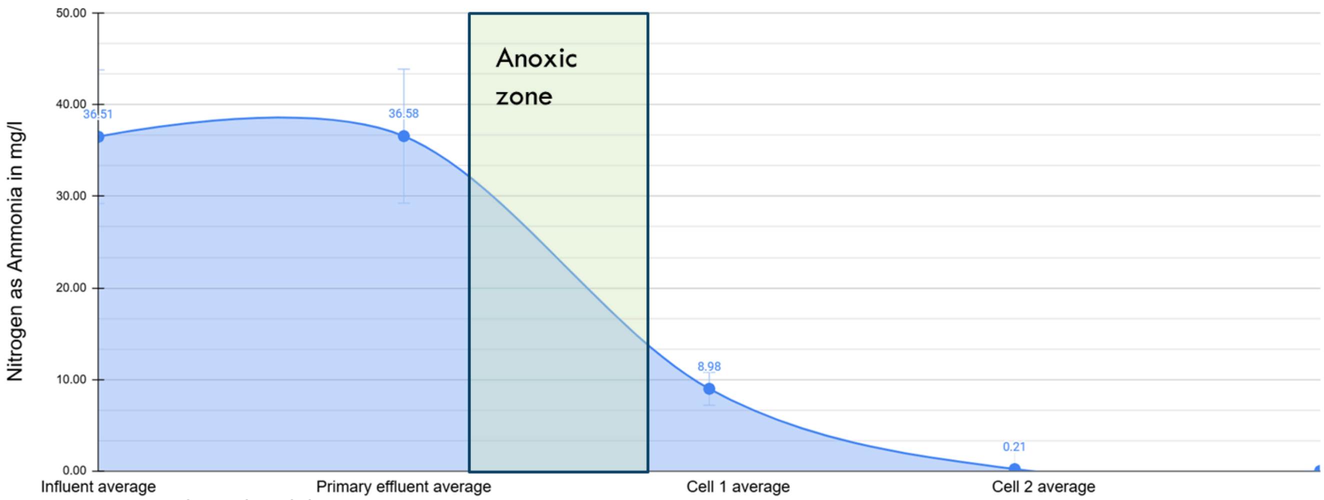

Figure 2: Ammonia reduction through the CWP

the nitrate residual in the final effluent. Statistical analysis of these two data sets show

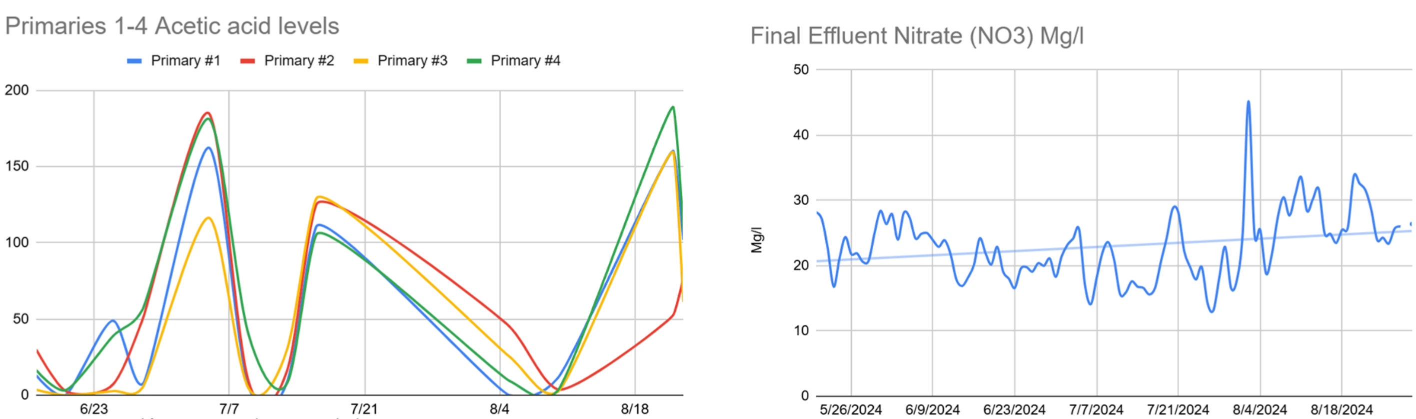

Figure 3: Acetic acid fermentation and nitrate residual.

a correlation coefficient of .2, suggesting a weak correlation between acidogenic fermentation and nitrate residual.

For the city of Wyoming, total government activities cost $257.8 million with $49 million in liabilities, leaving a net position of $ 209 million annually. About half of the city's total revenue comes from property taxes with the other half being split up between grants, other and charges for services rendered. Neither facility has any management in the public works department and operates independently. The revenue source for the clean water plant from the usage fees and fines from water and wastewater. Neither the drinking water or wastewater plants receive any funding from property taxes and are, in a way, financially independent from the city budget.The large majority of revenue comes from service surcharges. This is water and sewer fees, as well as industrial discharge fees. There is a small percentage of revenue that comes from various grants. Total revenue of $27.7 million dollar minus expenses of $21.7 million dollars puts the clean water plant having a surplus of $6 million dollars for the fiscal year 2024. The fiscal year for the city runs from July 1st to June 30. Although the surplus seems substantial, the facility still requires more overall expense than revenue can generate as aging infrastructure can cost millions of dollars to replace. With staggered end of life equipment, the plant is in a near-constant state of construction.

Although there was no correlation between acidogenic fermentation and denitrification efficiency, there are still additional cost-effective steps that will be taken in the future. Fermenting VFAs in a separate vessel is the most-cost prohibitive so this is not likely to occur in the near future. Taking additional samples for VFAs around the plant for additional data analysis is very cost-effective and has already begun. There are now 4 samples being taken 7 days a week throughout the plant. Using available lab resources to determine the microbial community in the anoxic zone. As is currently, the water quality of the Grand River is considered ‘good’ water quality by the state of Michigan’s standards as the water quality index (WQI) was routinely and consistently 70 or higher on a scale of 1-100.There is no evidence that the current nitrate discharge has any adverse effect on the river ecosystem, which may explain why there is currently no discharge limit on nitrate.

This internship has allowed for greatly increased knowledge of this facility's biological removal systems for nitrogen as ammonia and has provided the facility with a conversation starter involving a future VFA fermentation project. This knowledge will be applied towards both the class B and class A municipal wastewater treatment licensure through the state of Michigan. A class C is required for this position but operators for the city of Wyoming have a rare opportunity to acquire both a class A and B through the required accumulation of majority of operational responsibility (MOR) hours. This internship has also set the stage for future research and collaboration within the operations and laboratory staff at this facility.

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