Department of Biosystems and Agricultural Engineering
MICHIGAN STATE UNIVERSITY

BE 487 - Spring 2022
Biosystems Design Projects

BE 487 – Nitrogen Stripping and Ozonation Columns for Wastewater Treatment in Remote Army Bases

Melanie Stoughton, Jack Kivi, Arun Kammanadiminti, and Skijlar Howerzyl

Client: DoD Faculty Advisor: Dr. Liao

Background

The United States Department of Defense (DoD) provides military forces that ensure the security and safety of the United States and its allies around the world. The DoD is currently focused on making their forward operating bases (FOB) run as independently as possible while also reducing the cost and security risks that come with the need for frequent water transportation. Therefore, a portable wastewater treatment system has been in development for approximately 3 years prior to the beginning of this project. The goal of the entire system is to be able to recycle and treat water available to the FOB and treat blackwater to the standard that it can be used for needs other than drinking water. The pre-existing unit contains an EC reactor, a settler, and an ultra-filtration system. This project is concerned with creating an intermediate step between the EC unit and the ultrafiltration system that will improve the current water treatment process in alignment with the projects objectives and constraints.

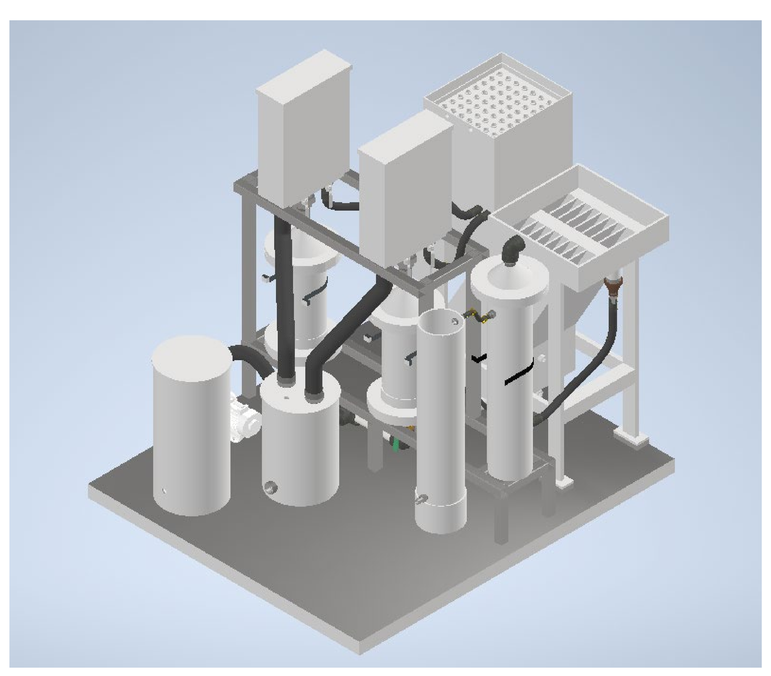

Figure 1: Complete System CAD

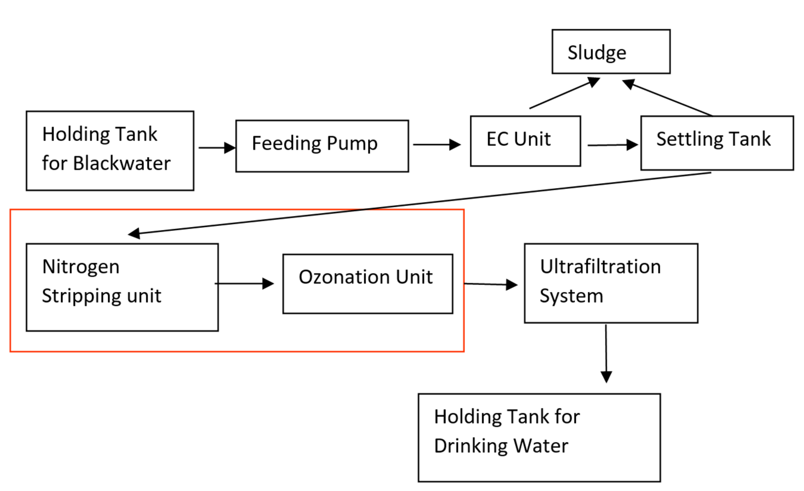

Figure 2: System Flow Diagram

Objectives

The objectives of this design project are as follows:

- Reduce ammonia levels in effluent water by 50%
- Reduce COD levels in effluent water by 75%
- Increase speed of the current system to less than 8 hours
- Turbidity less than 20 NTU

Constraints

There are a few constraints that dictate the design of the project:

- Must fit within a 17 in (width) by 17 in (depth) by 78.75 in (height)
- Be able to handle flow rates between 30 gal/hr and 120 gal/hr
- Be able to be transported by no more than 2 soldiers

Design Alternatives

There are many methods to treat wastewater that were considered in the selection of this design. The systems that were seen to be most effective for this designs purposes were aeration, ozone treatment, and nitrogen stripping.

Aeration

- Introduces O_2 into the water causing volatile and dissolved substances to leave the water as gases
- Up to 60% ammonia reduction
- 1-2 days for effective treatment of 1L

Ozone treatment

- Ozone microbubbles react with ammonia to form nitrate molecules
- Lower pH reduces ammonia reduction
- Around an hour for effective treatment of 1

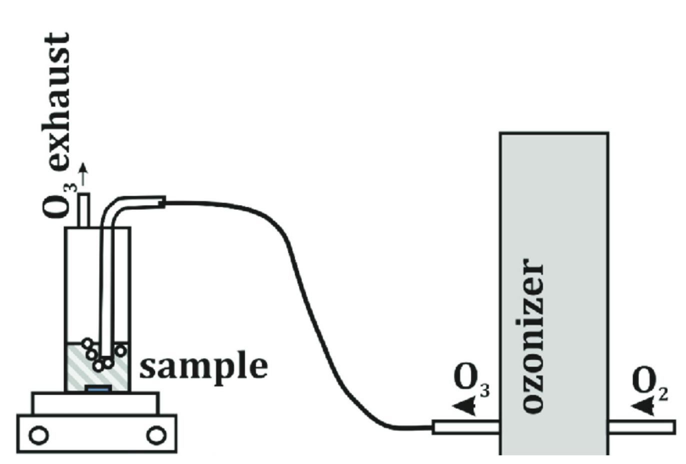

Figure 3: Ozone Treatment Schematic

Nitrogen stripping

- Separates ammonia from water turning it into a gas
- Up to 90% ammonia reduction with high pH
- Minimal effect on turbidity

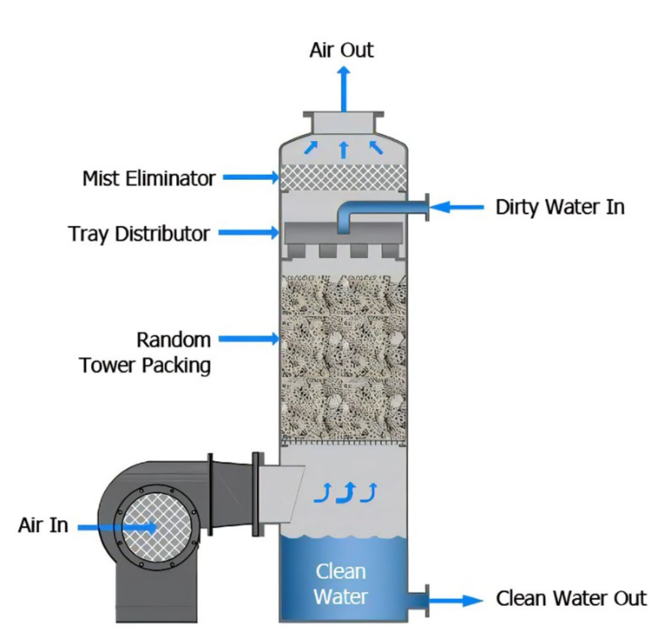

Figure 4: Nitrogen Stripping Schematic

Selected Design

Based on the different design alternative's ability to reduce ammonia levels, COD levels, turbidity, and reaction time, ozone treatment and nitrogen stripping were selected as methods of treatment for this design.

- Combination of ozonation and nitrogen stripping
- Both treatments work better in high pH
- Potential for 90% ammonia removal
- High COD removal
- Treatment time no greater than 3 hours
- Turbidity reduction minimal

Design Parameters

- Turbidity – improved water clarity
- Reaction Time – reduced time for progression of water treatment
- Ammonia Reduction – removal of ammonia (in ammonium ions and ammonia) from influent water
- COD – reduction in oxygen required to break down pollutants
- Variable Flow Rate – ability to adjust flow based on FOB needs

Prototype Testing

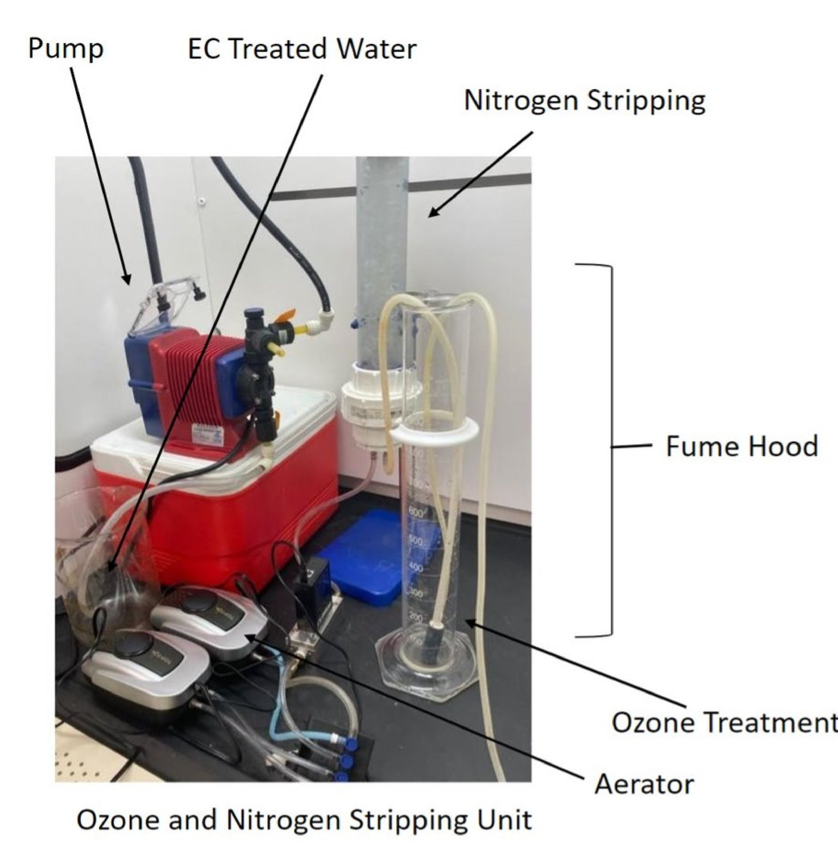

Figure 5: Prototype Set Up

Table 1: Test with pH Adjustment

Treatment Stage	Turbidity (NTU)	COD (mg/L)	Ammonia (mg/L)
Pretreatment	62.6	488	259.5
Nitrogen Stripping	105	500	156.5
Ozone	100.8	436	12.55
Reduction	-61%	11%	95%

Table 2: Test without pH Adjustment

Treatment Stage	Turbidity (NTU)	COD (mg/L)	Ammonia (mg/L)
Pretreatment	62.6	488	259.5
Nitrogen Stripping	93.05	485.5	238.5
Ozone	51.3	452	121.4
Reduction	18%	8%	53%

Design CAD Drawings

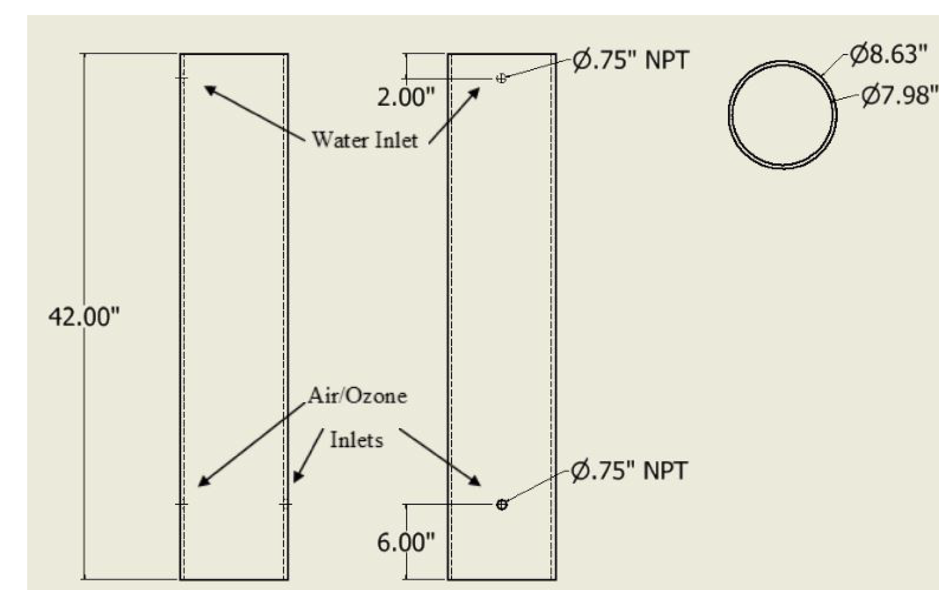

Figure 6: Column Drawing

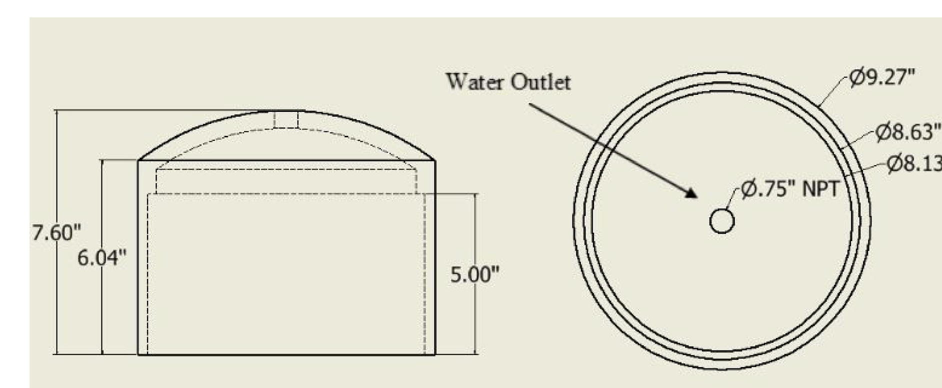

Figure 7: Cap Drawing

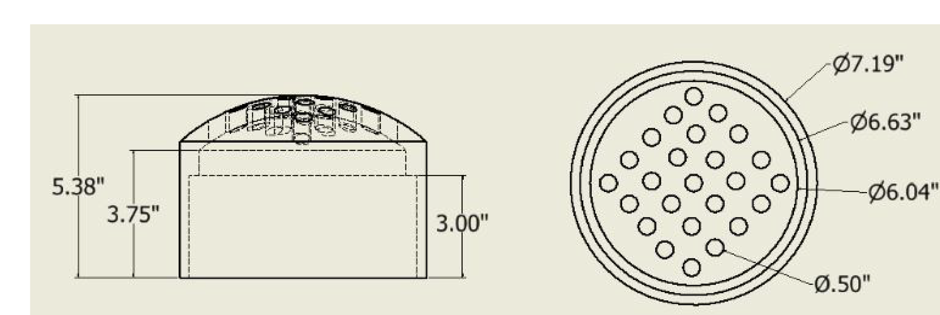

Figure 8: Nitrogen Stripping Grate Drawing

Economics

Capital cost estimate: $2,500

- Prototype: $1000
- Ozone generator: $1000
- Air fan: $500

Variable cost estimate: $326.73/year

- Run-time per day for 365 days: 4 hours
- Power for devices: 0.62 kW
- Price of electricity: $0.14/kWh
- Maintenance: $200/year
- Water use: 87600gal/year

Results

Figure 9: Fabricated Columns

Testing without pH adjustment

- Ammonia: 53 % Reduction
- COD: 8% Reduction
- Turbidity: 18% Reduction

Testing with pH adjustment

- Ammonia: 95% Reduction
- COD: 11% Reduction
- Turbidity: 61% Increase

The requirements for ammonia reduction were met under both tests with and without pH adjustment. The design and supplemental components(ozone generator and air blower) all fit within the prescribed area. The COD and turbidity reductions were not met, and turbidity increased with the addition of chemicals to increase pH. The design is scaled to run at 60 gal/hr and the longevity of the system will be investigated this spring with testing at this flow rate.

Figure 10: Effluent from EC unit

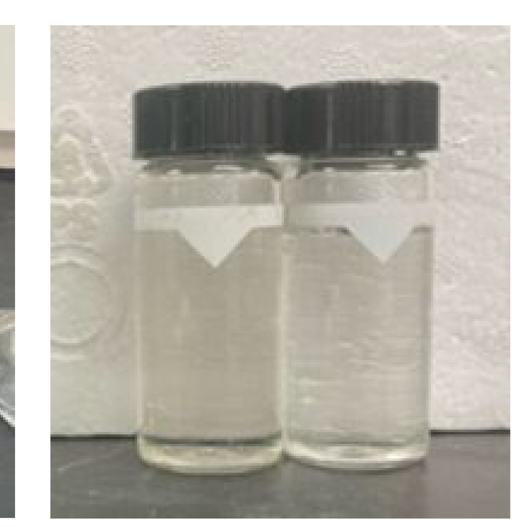

Figure 11: Effluent after Treatment

Select References

U.S. Environmental Protection Agency. (2004, June). *Understanding the safe drinking water act.* https://www.epa.gov/sites/default/files/2015-04/documents/epa816f04030.pdf.

U. S. Environmental Protection Agency. (2009, May). *National primary drinking water regulations.* Office of Ground Water and Drinking Water. https://www.epa.gov/sites/default/files/2016-06/documents/npwdr_complete_table.pdf

United States Geological Survey. (n.d.). *Sediment and suspended sediment.* https://www.usgs.gov/special-topic/water-science-school/science/sediment-and-suspended-sediment?qt-science_center_objects=0#qt-science_center_objects.

Bilińska, L., Blus, K., Gmurek, M., & Ledakowicz, S. (2019, February 15). Coupling of electrocoagulation and ozone treatment for textile wastewater reuse. *Chemical Engineering Journal*, *358*(1), 992-1001. https://doi.org/10.1016/j.cej.2018.10.093.