Department of Biosystems and Agricultural Engineering
MICHIGAN STATE UNIVERSITY

BE 487 - Spring 2022
Biosystems Design Projects

BE 487 - Mobile decentralized treatment system for domestic septage utilizing innovative aeration (Under NDA)

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Background

Septage is generated when wastewater from the home enters domestic septic tanks. Septage sludge is stored anaerobically, and liquid effluent from the wastewater is sent into a drain field.

- Septage is difficult to treat due to its high level of solids and variability of physical characteristics
- >1 million Michigan homes and businesses use septic systems
- Septage treatment and disposal methods include:
  - Land application
  - Pure oxygen treatment
  - Activated sludge treatment
- Septage discharge and disposal is regulated by the EPA and Michigan EGLE
- This system is based around the PrO2 series equipment by Greener Planet Systems
  - Biological treatment mechanism
  - Water is supersaturated with oxygen
  - This is added to the septage via slipstream for treatment
  - Dissolved Oxygen saturates the water so minimal loss of oxygen by off-gassing

Problem Statement

Design a mobile decentralized treatment system that accepts loads of domestic septage and treats them to acceptable wastewater treatment plant discharge parameters through the incorporation of Greener Planet Systems' PrO2 series equipment.

Objectives

The final deliverable of this project is a system design that can treat an input of domestic septage to be discharged to a wastewater treatment plant at no additional cost. The following objectives have been completed:

- Experimentally determine the septage treatment capabilities of the PrO2
- Evaluate the end fate of liquids and solids generated by the treatment process
- Determine an optimal system design that will treat 20,000 gal septage/day to the municipal sewage discharge levels

Constraints

- Septage must be treated to concentrations analogous to low-strength wastewater. These values are outlined in Metcalf & Eddy (2013).
- The final system design must be mobile

Experimentation

- Experimentation was used to determine characteristics of septage, and required treatment time of PrO2
  - Treated septage should match concentrations of low-strength wastewater
- Treated septage in a small-scale sequencing batch reactor using the PrO2 series equipment
  - Volume: 125 gal septage treated with oxygenated water
  - Time: 48-hour period
  - Mixing: semi-continuous
  - 4 trials were run with different flowrates of PrO2 water
  - DO, COD, NH_3, NO_3, TSS, TS, and pH were monitored over the trials
  - Other parameters were analyzed through Merit Labs

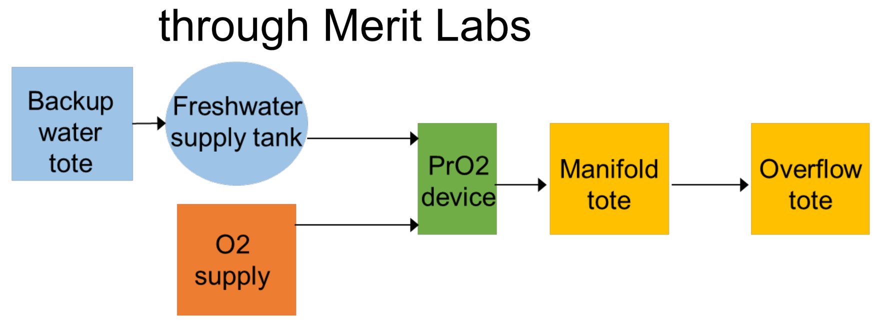

Figure 1: Experimentation treatment process

- Results indicate that 24-30 hours is a sufficient treatment duration

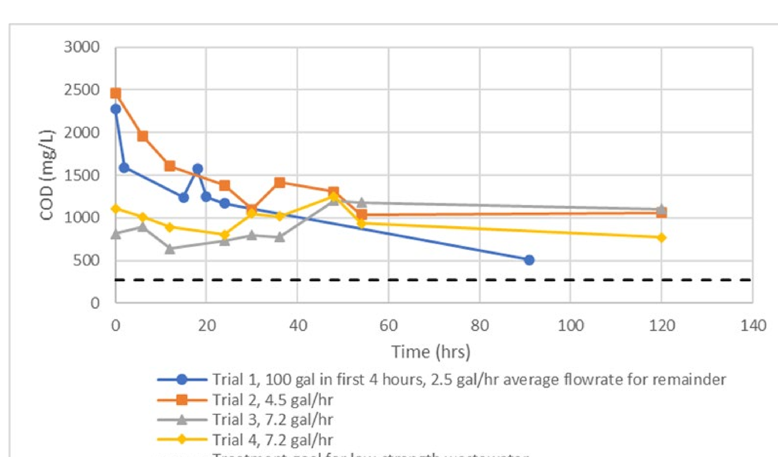

Figure 2: Change in COD concentration (mg/L) over treatment duration

Table 1: Averages of the initial and final parameters of all trials

Parameter	Initial (mg/L)	Final (mg/L)	% reduction	Low-Strength WW (mg/L)
COD	989	1096	-10.8	266
Ammonia (NH3)	78.4	40.5	48.3	20
Phosphorus (Total)	13.1	4.97	62.0	3.7
Nitrogen (Total)	88.8	64.1	27.8	23
Chloride	1549	567	63.4	39
Potassium	24.0	21.4	11.0	11
TSS	7597	2314	69.5	130

Selected Design

The final selected design can be broken down into five main components:

1. Coarse Screening
   - Used to separate the larger solids from the influent septage to prevent damage to the machinery and to increase overall treatment efficiency.
   - Final design utilizes a vertical bar rack capable of removing solids larger than 0.24 in.
   - Rack will be placed onto the top of the equalization tank and will be removed after septage is pumped to be manually cleared.
2. Equalization
   - Influent septage is pumped into the main equalization tank, where it is prepped to be pumped into the rest of the system for treatment.
   - Final design utilizes a 21,000-gal capacity chemical mixing frac tank with four 10 hp motors for mixing. This tank has been designed to be attached to a semi-truck and is mobile.

https://sprintindustrial.com/tidal-tank/storage-solutions/mix-tanks/

Figure 3. Frac tank for mixing

3. Aerated Treatment
   - Septage is treated with PrO2, which injects water supersaturated with oxygen into the target waste stream.
   - PrO2 is fed through a series of 3 3,000-gal poly tanks filled water and returns the oxygenated liquid into an additional series of 3 3,000-gal poly tanks.
   - Oxygenated water is then pumped into batch reactors, which consist of interlinked two 6,000-gal polyethylene tanks, each equipped with a 10 hp mixing motor.
   - Design utilizes two batch reactors, with an additional 6,000-gal tank to act as an overflow buffer.

http://greenerplanetsystems.com/pro2-series/.

Figure 4. PrO2 treatment device

Selected Design cont.

4. Chemical Conditioning
   - After the septage has been treated in the reactors for 24 hours it is pumped into an additional 21,000-gal mixing frac tank, and a smaller 8,400-gal mixing frac tank.
   - Metal salts or liquid polymers are added into the septage to prepare it for dewatering.
5. Dewatering
   - A centrifuge was selected to separate the liquids and solids of the treated septage, so that the liquid can be discharged to a municipal treatment plant.
   - Centrifuge was chosen due to its smaller footprint, efficiency, and mobility

https://dolphincentrifuge.com/alfa-laval-nx-418-decanter-centrifuge/.

Figure 5. Alfa Laval NX 418 decanter centrifuge

Design Parameters

System will:

- Be mobile
- Treat to the same characteristics as low strength wastewater (BOD < 133 mg/L)
- Treat of 20,000 gal septage/day
- Utilize the PrO2 with a flow rate of 5-gal oxygenated water/min or 7,200 gal/day
- PrO2 will meter water flows based on DO levels in reactor tanks

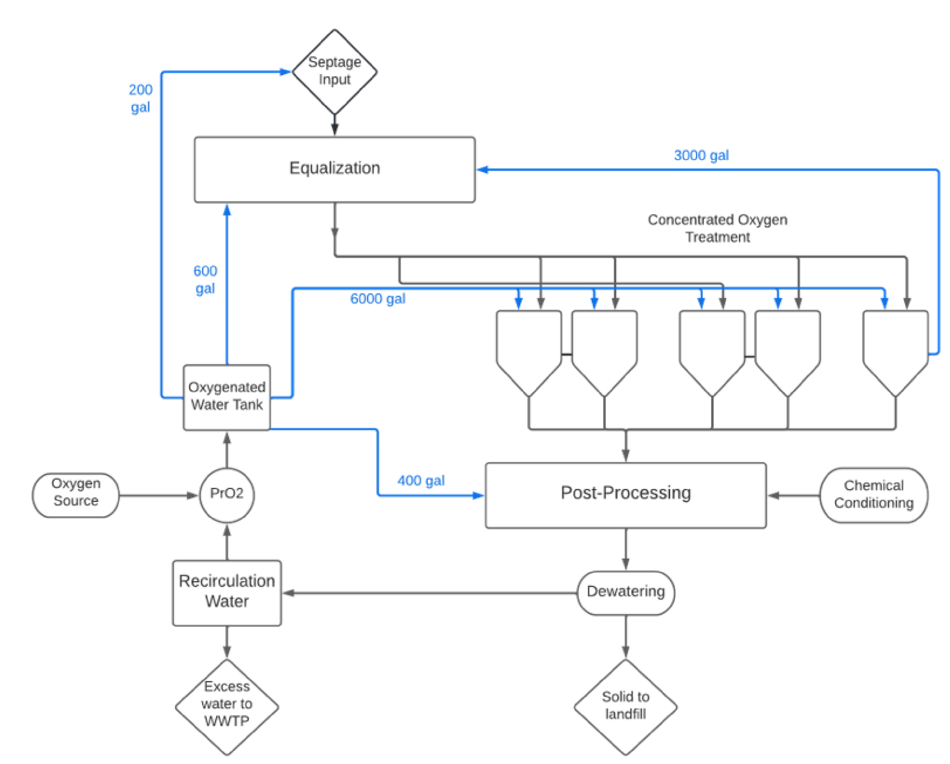

Figure 6. Treatment system process flows

Economics

Cost analysis compared capital and operation costs of the designed system to the current method of discharging untreated septage to the Livingston Wastewater treatment plant.

Table 2: Economic analysis summary table

	Units	Designed System	Current Method
Capital Cost	$	459,000	30,000
Operational Cost	$/10,000 gal	560	750
Operational Unit Cost	$/gal	0.06	0.08
Payback Period	yrs	6	

- Capital Costs
  - Conservative estimate with prices of new equipment
  - Accounts for current market variability
- Operational Costs
  - Based on treating 10,000 gal at system startup
  - Include oxygen, electricity, water, polymer and labor
  - Optimizable with reduction in oxygen and electricity use
- Payback period calculation

$$Payback\ Period = \frac{\$459,000}{\frac{\$(750-560)}{batch} * \frac{2\ batches}{day} * \frac{200\ day}{yr}} = 6\ years$$

Conclusion

- Determined PrO2 treatment capabilities, and collected novel data
- Septage not treated to the desired level
- Still efficiently treated and gained insight to develop mobile treatment system
- Designed mobile septage treatment system for 20,000 gal/day
  - Can be further optimized to meet user needs
  - High cost and uncertain treatment may not be a worthy investment

Select References

1. Greener Planet Systems. (2017, July 19). *Pro2 series.* http://greenerplanetsystems.com/pro2-series/.
2. Metcalf & Eddy, Tchobanoglous, G., Stensel, H., Tsuchihashi, R., & Burton, F. (2013). *Wastewater engineering: Treatment and Resource Recovery* (5th ed.). Mcgraw-Hill Medical Pub.
3. Michigan Department of Environment, Great Lakes, and Energy [EGLE]. (2022). *SepticSmart.* EGLE - Onsite Wastewater. https://www.michigan.gov/egle/0,9429,7-135-3313_71618_51002-455688--,00.html
4. United States Environmental Protection Agency. (1994, September). *Guide to Septage Treatment and Disposal.* EPA. https://www.epa.gov/biosolids/guide-septage-treatment-and-disposal.