Fertilizer from Wastewater: Biological Enhanced Phosphorous Removal and Steps to Commercialization

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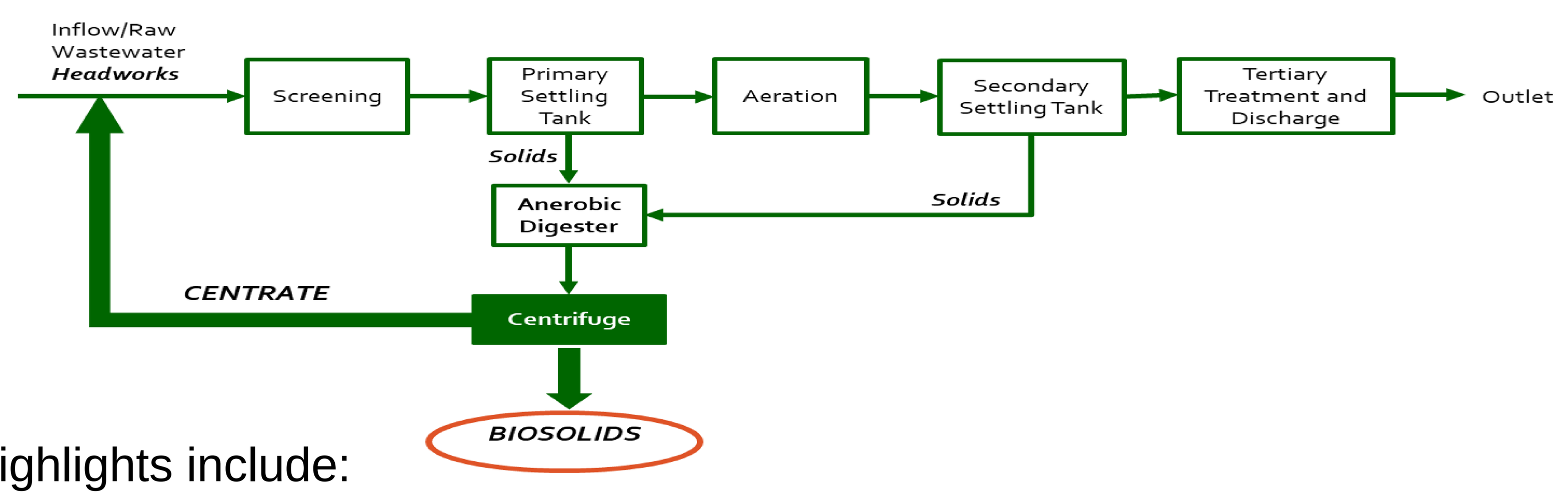
Background

The Problem

Nitrogen and phosphorous released from wastewater treatment plants contribute to eutrophication. In addition, mined phosphorous is a limited resource, and fertilizer production is an environmentally damaging process.

Prior Research

This project is a continuation of prior research on extracting magnesium ammonium phosphate (MAP) fertilizer from wastewater centrate. The figure shows the treatment process of the Easton wastewater treatment plant



Past research highlights include:

- Magnesium oxide (MgO) is a suitable magnesium source to produce MAP, and cheaper than alternatives
- A combination of settling and bubbling can aid in MAP formation
- It is possible to remove over 90% of phosphate
- The ideal reactor design is a fluidized bed reactor

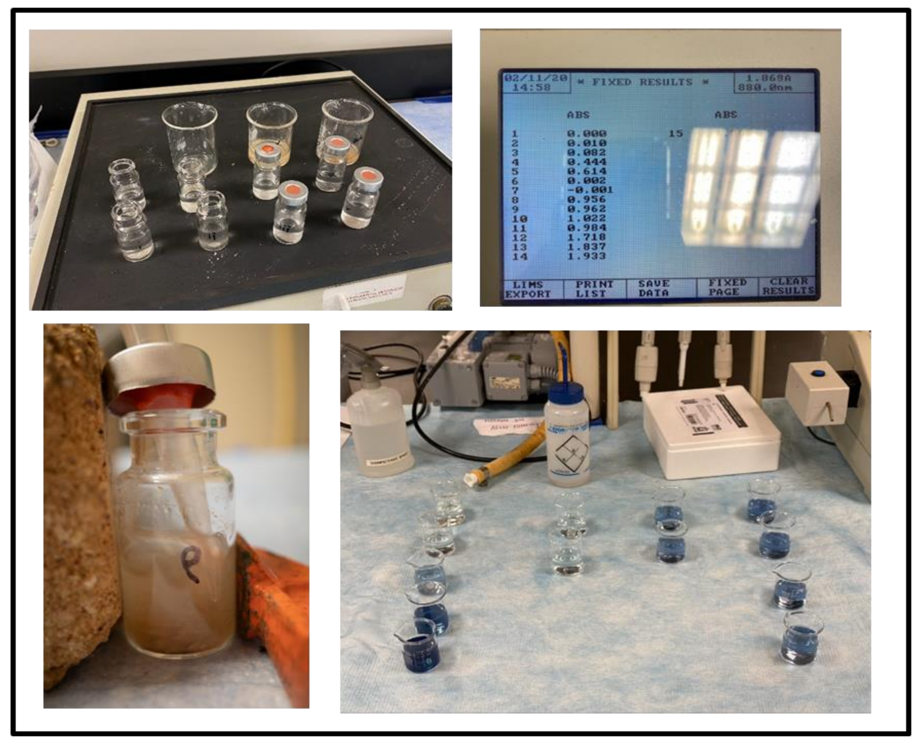
Biological Removal of Phosphorous

Goals

The goal of this research is to use phosphate solubilizing bacteria to extract additionally phosphate from post-digestion wastewater solids.

Methods

In this experiment, we used three Bacillus Subtilis strains (A1000, E923, E400) provided by Biosciences Inc.. The objective of this experiment is to release the phosphorous stored in the wastewater sludge through adding Phosphorous-Solubilizing strains. During the sring 2021 semester, the lab testing primarily focused on the A1000 and E923 strains. According to Saeid et al., the optimal condition for bacterial growth is 72 hours at 35 C. We used the same procedure to incubate the bacteria.



Steps to Commercialization

Goals

If commercialized, this technology couldd help improve the health of waterways and lower the environmental impact of agriculture. This project aimed to understand the barriers and opportunities for commercialization.

Methods

53 US cities with at least 50,000 people were randomly selected. I called their WWTP and ask to conduct an interview about how applicable our technology would be to them. I was able to conduct 12 interviews (seen on Figure 2).

The results of these interviews were used to construct a basic technoeconomic analysis spreadsheet to evaluate if our technology could be used at a specific site.

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Results

Biological Removal of Phosphorous

Both A1000 and E923 are Capable of releasing phosphate from wastewater sludge, but A1000 is more effective than E923.

	02/23/21	03/07/21	
Strain	P Removal (%)	P Removal (%)	Avg. P removal
A1000	1592.47	1580.01	**1586.24**
E923	1250.00	936.08	**1088.04**

Table 3: Phosphorous Removal Efficiency Comparison

Steps to Commercialization

Location	Size (MGD)	Struvite Problem?	Struvite Cost (per year)	Anaerobic Digester	Solids Disposal Method	Solids Disposal Cost (per year)	Recent Large Upgrades	Interest in Our System	Capacity to Sell Fertilizer	Approached by Commercial Vendor
Scranton, PA	46	Yes, uses alum	$26,208	Yes	Landfill	$95,000	$32,000,000	Yes	No	No
Bridgeport, CT	5	No	N/A	No	Incinerated for electricity	$1,100,000	Next few years $300-400,000,000	No	N/A	No
Poolesville, MD	0.750	Yes, uses alum	N/A	Yes	Landfill	$125,000	$1,500,000	No	N/A	Grignard
Dubuque, IA	7	Yes	Tens of thousands	Yes	Land applied	$275-300,000	$70,000,000	Yes	No	Airpex
Milwaukee, WI	3-4	No	N/A	Yes	Another WWTP	$60-70,000	$5,000,000	No	N/A	No
Westminster, CO	11.9	Yes, ferric chloride	N/A	Yes	Land applied	$1,500,000	$50,000,000	Maybe	Maybe	N/A
Henderson, NV	32	No	N/A	No	Landfilled	$1,000,000	N/A	No	N/A	No
Fort Worth, TX	95-115	Yes, ferric chloride	N/A	Yes	Land applied	N/A	Significant	Yes	Maybe	No
Palo Alto, CA	20	No	N/A	No	Land applied	N/A	N/A	No	N/A	No
San Francisco, CA	44	Used to	N/A	Yes	Landfilled, summer land applied	N/A	Tens of millions	No	N/A	N/A
Thousand Oaks, CA	14.5	Yes	N/A	Yes	Compost	N/A	N/A	Yes but wouldn't pay upfront	No	No
Seattle, WA	120	Yes, mechanical removal	N/A	Yes	Land applied	N/A	$15,000,000	Maybe	No	No

This research on commercialization of MAP production revealed several key insights:

- Large regional variation with plant design
- Large variation in disposal costs
- Regulatory mandate will play a big role in technology feasibility
- Prior bad experiences with new technologies could be a barrier

Using the customer interviews, I developed a technoeconomic analysis spreadsheet for siting prospective plants and the following equation:

$$\mathrm{R} = (S * P) + A - (E * U) - (D_S - D_0) - \mathrm{M} - \mathrm{T} - \mathrm{C} - \mathrm{CAPEX}[\frac{i(1+i)^n}{(1+i)^n - 1}]$$

Equation 1: Technoeconomic assessment of feasibility

Conclusions

MAP production from wastewater centrate and biosolids is an attractive technology to some WWTP operators. Proper marketing and explanation of the technology is an important step in its commercialization. Regional and plant-level differences will play a large role in where this technology can be commercialized. Many unknowns regarding cost and technical specification of the MAP producing fluidized bed reactor must be worked out prior to commercialization. Regulatory mandate will play a large role in attracting plants to this technology.

Future Work

The customer interviews raised many additional questions about the costs involved in our technology that need to be addressed. Understanding the regulatory landscape will also be helpful.

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