Microbial Bio-Solubilization for Enhanced Phosphorus Recovery from Wastewater Biosolids

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LAFAYETTE COLLEGE

Introduction

The Phosphorus Problem

- Phosphorus is a dwindling natural resource that is critical to global food supply
- 85-90% of mined phosphate is used for agricultural fertilizers
- Mining phosphorus introduces more reactive phosphorus leading to environmental degradation through eutrophication (Figure 1)
- Our research focuses on changing the current linear extraction process to a sustainable nutrient loop (Figure 2).

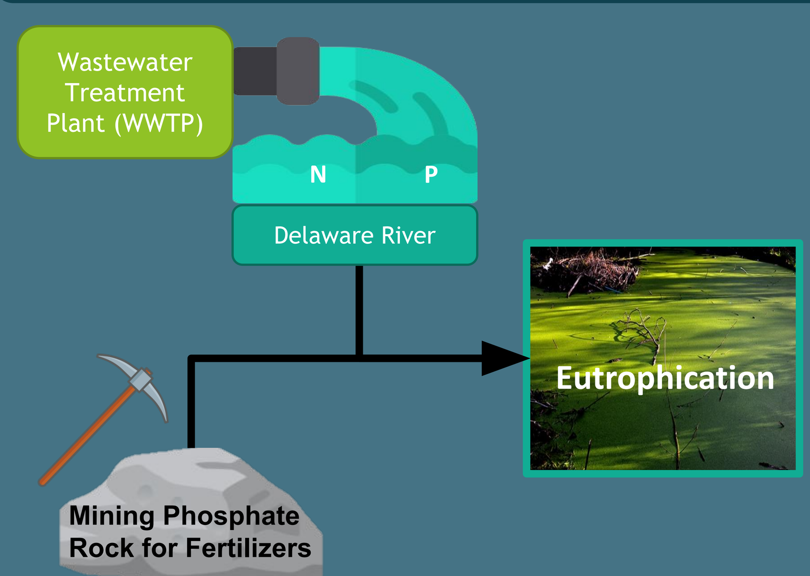


Figure 1: Sources of Eutrophication Our Research Aims to Mitigate

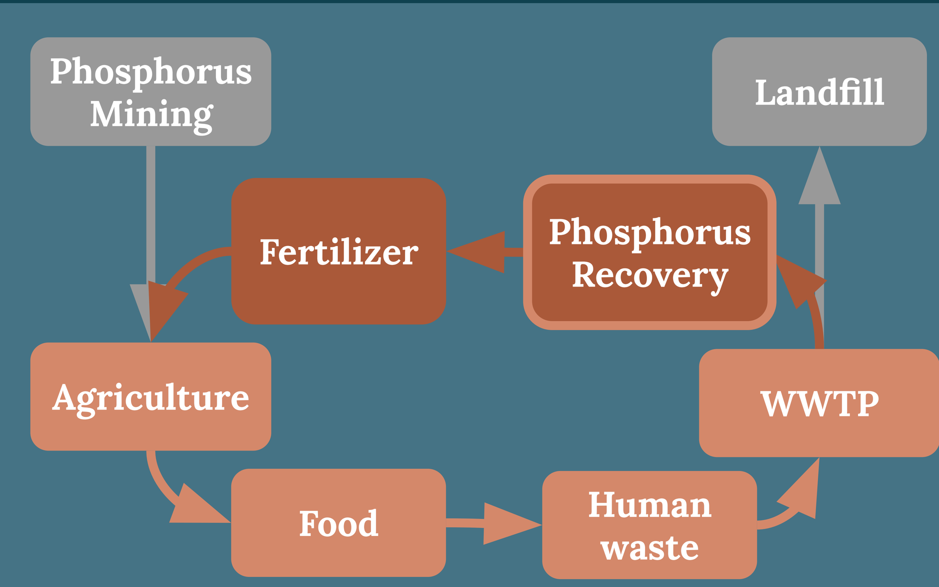


Figure 2: Sustainable Phosphorus Cycle Management through Phosphorus Recovery

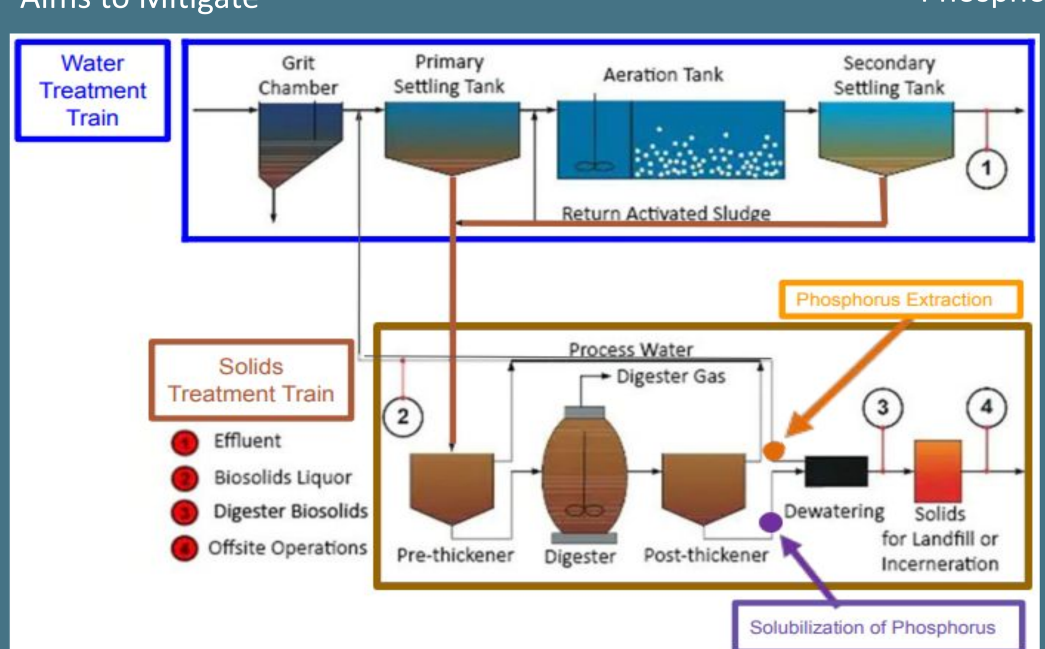


Figure 3: Typical Wastewater Treatment process train with Water Treatment Train and Solids Treatment Train highlighted (Adapted from Web Image)

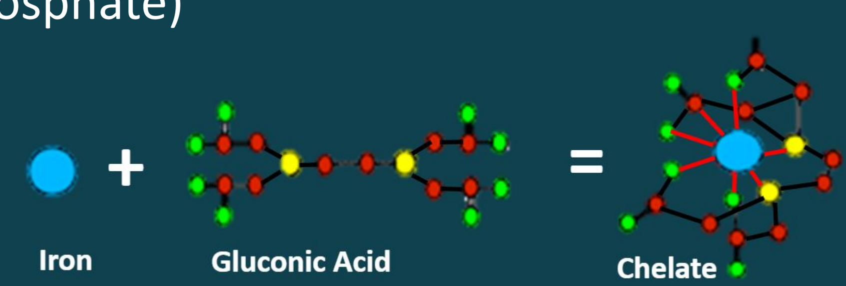
Figure 4: Three strains of bacillus bacteria (A1000, E400, and E923) being tested

Goal of Research

- Wastewater biosolids are typically incinerated and/or sent to landfills despite their richness in nutrients
- The *Bacillus* species of bacteria is utilized to liberate phosphorus from unavailable, insoluble structures bound in the biosolids before dewatering (Figure 3)
- After increasing the soluble phosphorus concentration, the biosolids are sent through a centrifuge in the WWTP (Figure 3)
- The supernatant fluid will be subjected to some method of phosphorus extraction to convert the phosphorus into a usable form (Figure 3)

Bio-solubilization with *Bacillus*

- *Bacillus* bacteria (Figure 4) produces low molecular weight organic acids (Gluconic, Lactic, Acetic, Succinic, and Propionic acids) which interact with insoluble/low solubility forms of phosphorus in the biosolids (Tricalcium Phosphate, Iron Phosphate, Aluminum Phosphate)
- These organic acids have hydroxyl and carboxyl groups that form chelates with the metal cations like iron which liberate the bound phosphorus



Progression of Research

Past Research

- Blind test with Monera Technologies using phosphorus solubilizing bacteria
- Moved from spectrophotometry to ion chromatography
- Narrowed range of incubation time (24 - 48hr), temperature not a significant variable (33 - 37°C)
- Inherent variability of biosolids leading to inconsistent results
- Identified need for pre-culturing bacteria and autoclaving laboratory equipment

Current Research

- Use the *Bacillus* strain to solubilize phosphorus to enhance phosphorus recovery through ion exchange or another method
- Developing a process to effectively aerate bacteria during incubation

Table 1: Experimental and control sample treatments

Time (hrs)	Unincubated	Incubated at 34°C		
24	Biosolids Control	Biosolids Control	Biosolids + Bacteria	Bacteria Control
48	Biosolids Control	Biosolids Control	Biosolids + Bacteria	Bacteria Control

Methods

- Bacteria samples are pre-cultured. Samples of biosolids and bacteria are prepared and incubated under 8 different treatments (Table 1), then filtered
- Concentration evaluated through Ion Chromatography

Table 2: Phosphorus Concentrations for Various Testing Parameter

	Unincubated Samples	Samples Incubated at 34°C		
Time (hrs)	Biosolids Control (ppm P)	Biosolids Control (ppm P)	Bacteria and Biosolids (ppm P)	Bacteria Control (ppm P)
24	1.5	2.7	23.9	13.3
48	1.4	3.5	25.0	14.3

$$\%\ P\ \text{Increase by Bacteria} = \left[\frac{\text{Biosolids and Bacteria ppm} - \text{Biosolids ppm} - \text{Bacteria ppm}}{\text{Biosolids ppm}}\right] \times 100$$

Equation 1: Equation for Determining Percent Increase by Bacteria

Results

- The equation (Equation 1) is used to calculate % Phosphorus increase (Table 3) based on concentrations present in test samples (Table 2).
- The decrease in % P increase from 24 to 48 hrs is hypothesized to be due to competition from the bacteria in the biosolids.
- The increased concentration from unincubated to incubated biosolids shows that heat also solubilizes phosphorus.

Table 3: Percent Phosphorus Concentration Increases

Time (hrs)	% P increase by Bacteria	% P increase by Bacteria and Biosolid Incubation
24	353	618
48	309	599

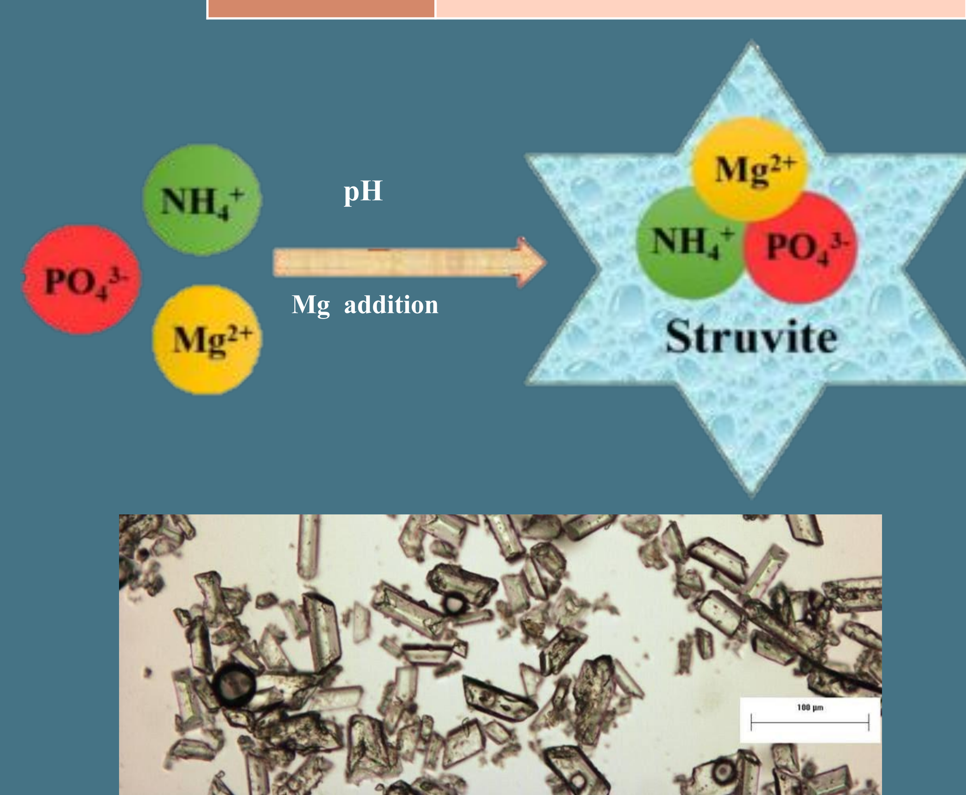


Figure 5: Diagram showing struvite precipitation process and examples of struvite crystals

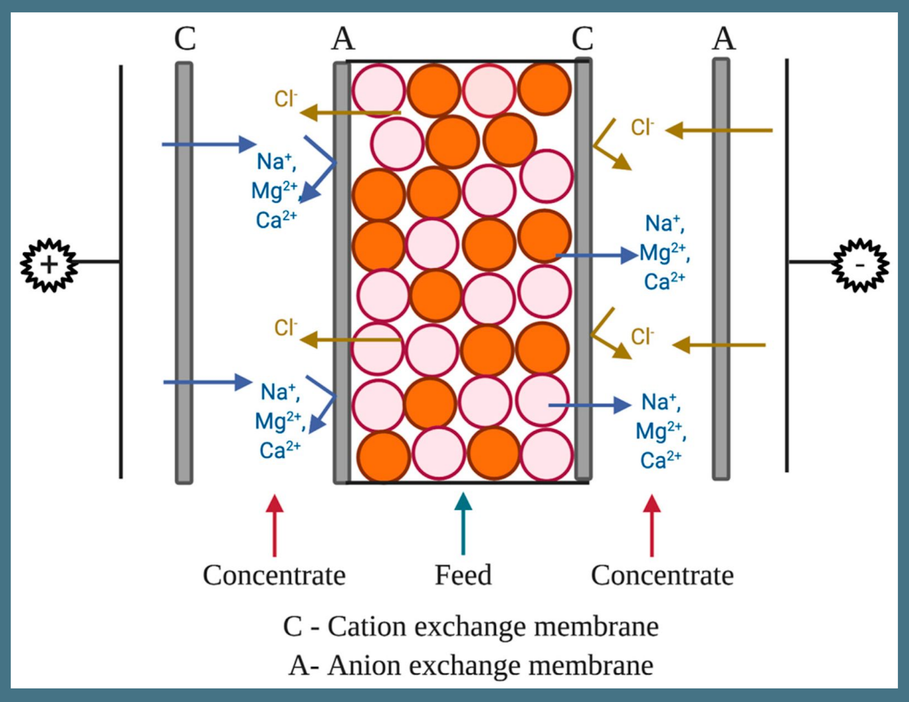


Figure 6: Diagram demonstrating the method of selective ion exchange

Future Research

- Continued optimization: Aeration, quantifying bacteria, understanding competition
- Extraction methods: evaluate benefits of MAP precipitation (Figure 5) and ion exchange (Figure 6)
- Logistics of implementation, cost analysis

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