Sustainable Phosphorus Recovery and Reuse

Sustainability and Social Entrepreneurship Fellowship (Spring 2024)

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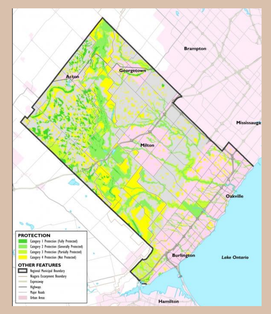
Overview

Halton Region, part of Canada's rapidly growing Golden Horseshoe, boasts a diverse urban population and a rich agricultural area. It hosts one of North America's largest food and farming clusters, producing over 200 types of crops and housing most of Ontario's food processing operations. Halton is actively working towards a circular economy by implementing strategies for sustainable water, wastewater, and solid waste management.



Problem Statement

Phosphorus is vital for agriculture, yet sources of phosphorus are becoming depleted. Additionally, phosphorus used in agriculture enters local bodies of water from runoff, leading to the environmentally destructive process of eutrophication.

Objective

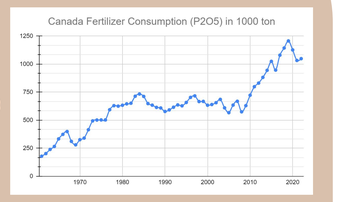
Our main objective is to develop and implement sustainable phosphorus management strategies in Halton. We aim to:

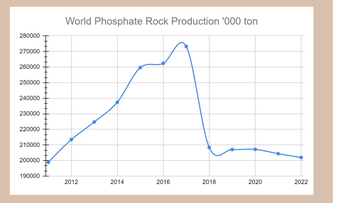
- Promote phosphorus recovery and recycling.
- Reduce phosphorus runoff to prevent eutrophication.
- Optimize phosphorus use for soil fertility and crop productivity.
- Develop regional value chains instead of relying on imports.

Main Concerns

Diminishing Phosphorus Availability

- Phosphorus use is increasing.
  - Consumption of fertilizers (P2O5) in Canada increased from 1961 to 2022.
- Phosphate rock production is decreasing as natural sources are becoming diminished.
- Canada has no domestic phosphate reserves and relies on imports. Thus it is vulnerable to market fluctuations from potential geopolitical instabilities.





Environmental Destruction from Eutrophication

- Up to 80% of phosphate applied to agriculture is lost to soil tie-up, nutrient runoff and leaching.
- Runoff leads to nutrient overloads in waterways. This is a series form of water pollution.
- Due to excess phosphorus in waterways, high rates of algae bloom and then die, lowing the oxygen in the surrounding area.
- This process creates “dead zones” where aquatic life cannot survive.
- This issue is present in Halton:
  - Hamilton Harbour has historically suffered from nutrient loads from waste water treatment plants and agricultural runoff entering from tributary inputs, resulting in severe eutrophication.
  - Changes in dissolved oxygen in Sixteen Mile Creek, Halton, have negatively impacted species diveristy and health.

Phosphorus Wasted : Potential for Circularity

- Only 20% of the phosphorus in phosphate rock reaches the food consumed globally:
  - 30% to 40% is lost during mining and processing
  - 50% is wasted in the food chain between farm and fork
- Only half of all manure is recycled back into farmland around the world.

Solutions

Urban wastewater offers a rich and underutilized source of phosphorus. This is especially applicable to Halton, as its population is expected to grow considerably. It is projected that the population will double to 1.4 million by 2050.

Different technologies exist for recovering phosphorus from wastewater and creating value added products. The ideal technology would have the maximum possible recovery rate of phosphorus, be favorable economically, and produce a fertilizer that is effective. Choosing between technologies is a tradeoff between these factors. The highest recovery rates of phosphorus are taken from sewage sludge ash, however incineration of sludge is not a practice occurring in Halton. So, a technology that we focused on is the slow crystallization method. A specific company we would recommend is called OSTARA, and already has implemented its technology in many wastewater treatment plants in the US and Canada.

Value Added Product:

- With slow crystallization, nutrients crystallize into fertilizer granules which can be marketed and distributed to agricultural business.
- The recovered materials are MAP ($MgNH_4PO_4 * 6H_2O$) crystals. With this product, 100% of the phosphorus is plant available. This is not true for all products made from recovered phosphorus – for example other technologies produce calcium phosphate which has inconsistent plant availability.
- With MAP, direct agricultural application is possible as the product comes in a grain size that is market ready. Other technologies create recovered material that is powdery or dusty, requiring further treatment processes such as granulation.

Costs + Savings: Positive ROI:

- Costs are driven by buying and installing the necessary equipment. Due to economy of scale, investment costs can be reduced for larger treatment plants. A wastewater treatment plant (WWTP) with a population load of 200,000 people can have reduced investment costs of up to -50% compared to one with a population load of 100,000 because of the increased level of production. For this reason we would recommend selecting the Mid Halton WWTP first as it is the largest, serving a population of 289,602.
- Conventional processes of phosphorus removal encounter an issue where phosphorus, ammonia, and magnesium in the sludge form struvite (magnesium ammonium phosphate). This coats pipes and WWTP equipment, reducing flow and increasing maintenance costs.
- Savings in chemicals, sludge disposal, and maintenance, alongside revenues from product sales mean that the revenues and savings exceed the annual costs. Capital costs are recuperated within 5-10 years.

Key References:
[1] IFASTAT, https://www.ifastat.org/ (accessed Jul. 21, 2024).
[2] J. Elser and E. Bennett, "Phosphorus: Essential to Life—Are We Running Out?," Columbia University's Earth Institute, Apr. 01, 2013. [Online]. Available: https://news.climate.columbia.edu/2013/04/01/phosphorus-essential-to-life-are-we-running-out/. (Accessed: July 22, 2024).
[3] Ostara, "Nutrient Recovery Solutions," Ostara, [Online]. Available: https://www.ostara.com/nutrient-recovery/nutrient-recovery-solutions/. (Accessed: July 23, 2024).
[4]R. Siegel, "Sustainable phosphorus management: A systems approach," Science of The Total Environment, vol. 543, pp. 467-479, Dec. 2016. [Online]. Available: https://pdf.sciencedirectassets.com/271800/1-s2.0-S0048969716X00186/1-s2.0-S0048969716314656/main.pdf. (Accessed: July 23, 2024).