2019 WERC Design Contest

TASK 5

Removal and Reuse of Phosphorus as Fertilizer from CAFO Runoff

Background Information

Nutrient pollution caused by runoff from Confined Animal Feeding Operations (CAFO) and wastewater treatment plants is a major threat to aquatic ecosystems. The vital plant nutrient phosphorous can be carried away by CAFO runoff. This runoff can find its way into nearby streams, ponds, or other bodies of water and pollute local water ways. The buildup of excess water-soluble phosphorus can cause extensive algal or bacterial growth [1]. Algae blooms can block the sunlight from reaching a lake or stream bed causing the death of aquatic plants. When the algae itself dies and begins to decay oxygen in the water is consumed. Low oxygen levels in the water then cause the death of fish and other aquatic life. According to the EPA [2], climate change has accelerated the growth of algae blooms by causing temperature increases in surface water. Therefore, phosphorus runoff is an ever-increasing threat to the health of the world's water ways.

In dry areas of western United States, where water is scarce, CAFO runoff is collected and used as irrigation water. Therefore, the excess phosphorus is dissipated into the soil and utilized by the plants. However, in the eastern U.S., where rainwater is abundant, the runoff is not needed for irrigation. CAFO runoff is instead collected in large impoundment lagoons where it can infiltrate into the soil. Sectioning off large sections of land as impoundment lagoons that can store a year's worth of runoff is an inefficient use of natural resources. A more efficient method would be to create small catchment ponds where the CAFO runoff can be treated and drained into nearby streams or rivers. The removal of water-soluble phosphorus from runoff also presents an opportunity for the recovery of phosphorus for use as a fertilizer. This is especially important because easily extractible phosphorus has become scarce in recent years, raising the need for sustainable phosphorus recovery practices [3].

Problem Statement

Your team must design a water treatment system that can remove and recover water-soluble phosphorus from CAFO runoff. The phosphorus that is removed from the contaminated water should be easily reusable as a fertilizer.

Design Conditions

Your teams must design must achieve the following outcomes:

- Treat 20 Liters (5.28gal) of synthetic water that has an orthophosphate concentration of 20ppm
- Remove and recover as much phosphorus as possible. Teams will be judged on the total mass phosphorus removed
- Recovered phosphorus should be in a solid form with a moisture content of less than 25%
- Treatment method should be cost effective and efficient

- Processes should be easily scalable to accommodate high volume runoff from CAFO facilities

Evaluation Criteria

Each team is advised to read the Participation Guide for a comprehensive understanding of the contest evaluation criteria. Please visit the WERC website: https://iee.nmsu.edu/outreach/events/international-environmental-design-contest/guidelines/ for a copy of the Public Involvement Plan and Participation Guide and other important resources. Additionally, our design will be evaluated based on how well it addresses the problem statement and design conditions including:

- Safety considerations taken by your team during the demonstration and safety of the proposed commercial product
- The total amount of phosphorus recovered in a usable form as fertilizer
- Innovativeness, functionality, and reliability of the design
- Scalability of the bench scale demonstration to commercial CAFO flow volumes
- Thoroughness of the economic analysis and projected operating costs of the water treatment process
- Technical fundamentals

Past Works

Yang et al [4] proposed using algae to remove and recover phosphorus from collected agricultural runoff. The algae grown in the reclaimed water can be used to create biofuel and fertilizer.

Runoff from agricultural fields can also be treated to remove phosphorus. The removed products can then be reused as fertilizers. Common water treatments for Phosphorus removal include anion exchange followed by precipitation, biological removal with microorganisms, and chemical adsorption [5].

References

[1] Minnesota Pollution Control Agency, "Nutrients: Phosphorus, Nitrogen Scources, Impact on Water Quallity," May 2008. [Online]. Available: https://www.pca.state.mn.us/sites/default/files/wq-iw3-22.pdf. [Accessed 29 May 2018].

[2] Agency, U.S. Environmetal Protection, "What are some causes of cyanobacterial blooms?," 12 December 2017. [Online]. Available: https://www.epa.gov/nutrient-policy-data/causes-and-prevention. [Accessed 29 May 2018].

[3] D. Cordell, A. Rosemarin, J. J. Schröder and A. L. Smit, "Towards global phosphorus security: A systems framework for phosphorus recovery and reuse options," *Chemosphere*, vol. 84, no. 6, pp. 747-758, 2011.

[4] Y. Yang, X. Shi, W. Ballent and B. K. Mayer, "Biological Phosphorus Recovery: Review of Current Progress and Future Needs," *Water Environment Research,* vol. 89, no. 12, pp. 2122-2135, 2017.

[5] S. K. Ramasahayam, L. Guzman, G. Gunawan and T. Viswanathan, "A comprehensive review of phosphorus removal technologies and processes," *Journal of Macromolecular Science,* vol. 51, no. 6, pp. 528-545, 2014.