Determining the Ability of Polyphosphate Accumulating Organisms to Use Organic Compounds in Algal Photosynthate

Justus Smith[1,], Qichen Wang[2], and Brendan Higgins[3]*

[1] Undergraduate Student, Department of Biosystems Engineering, Auburn University
[2] Postdoctoral Researcher, Department of Biosystems Engineering, Auburn University
[3] Assistant Professor, Department of Biosystems Engineering, Auburn University

In current methods of wastewater treatment, aerobic bacteria play a vital role in the degradation of pollutants and the purification of waste. However, these bacteria require high levels of oxygen to operate, leading most treatment plants to synthetically aerate their systems. This process is costly and adds significant expense to a system that already incurs deficit spending to create.

In searching for an alternative to oxygenate these bacteria, photo-activated sludge systems have recently emerged as a possible solution (Mohamad et al., 2021). These systems use cultures of microalgae to oxygenate the aerobic bacteria rather than artificially, reducing the need for artificial aeration. As well, the presence of microalgae increased the abundance of certain bacteria, namely Polyphosphate Accumulating Organisms (PAOs). It is apparent that the algae and PAOs form a symbiotic relationship due to the algae's oxygenation, but little is known about the effect of algal secretions, also known as Algal Photosynthate (AP), on this relationship. Since PAOs are known to require carbon compounds, namely Volatile Fatty Acids (VFAs), and since similar carbon compounds to these are found in AP, it is possible that the interchange between these compounds significantly contributes to the relationship between the organisms.

Before work could be done to determine the effects of AP on PAO abundance and productivity, it was first important to develop a consistent source of PAOs for further use in the experiment. To do this, a sample of activated sludge was first taken from a local wastewater treatment plant in Columbus, Georgia, and added to a continuous reactor system developed specifically for this project (Fig. 1). This 1L seeding reactor would continuously cycle every 8 hours through a 1:4 ratio of VFAs and Artificial media, exporting half of its volume at the end of each cycle to allow for continuous nutrient uptake by the bacteria. In the 8 hour cycle, the reactor would consist of 5 phases: Feeding (hours 0-0.5), Anaerobic Operation (hours 0.5-2.5), Aerobic Operation (hours 2.5-5.5), a settling phase (hours 5.5-7.5), and a waste removal phase (hours 7.5-8). The reactor was also covered completely to prevent algal growth.

A unique component of PAOs that makes them especially useful for wastewater research is their ability to uptake phosphate in aerobic environments yet release phosphate in anaerobic environments. This oxic-anoxic synthesis and release allow researchers to manipulate phosphorus removal from wastewater by controlling the vacillation of these conditions. As well, since PAOs can operate in both presence and absence of dissolved oxygen, they can become the dominant bacteria in activated sludge where these cycles are present. To simulate aerobic-anaerobic cycling in the PAO seeding reactor, a fish tank aerator was attached to humidifying device and cycled on and off.

Fig. 1 PAO seeding reactor in operation.

[*] Corresponding Author: Justus@Auburn.edu

After the PAO seeding reactor was operated continuously for 1 month, a kinetic study was performed in which the reactor would be sampled every 30 minutes for one full cycle of the reactor. These samples would then be analyzed for pH, Optical Density, Dissolved Oxygen, and Total Phosphate levels to gauge favorable PAO growth conditions and the presence of PAOs.

Results of this kinetic study indicated that the reactor was truly operating under aerobic and anaerobic conditions (Fig. 2). As well it also showed concentrations of Phosphate increasing in the anaerobic phase of the cycle, and decreasing during the aerobic phase, indicating the presence of PAOs within the system (Fig. 3).

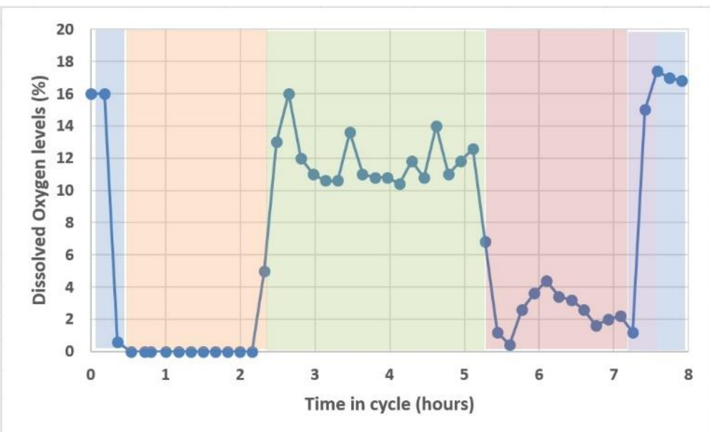


Fig. 2 Dissolved Oxygen Levels from Kinetic study on PAO seeding reactor.

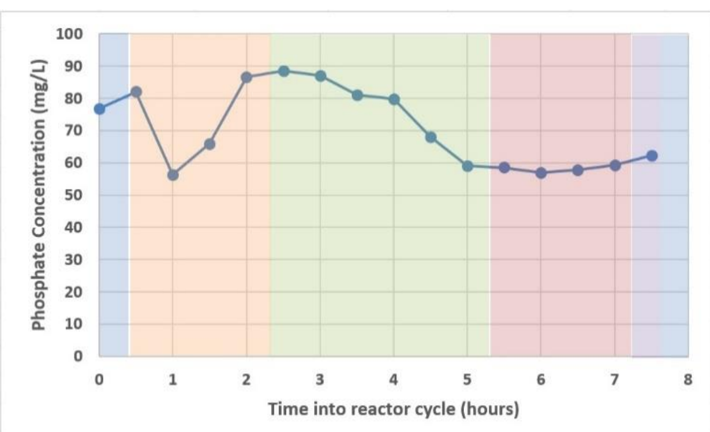


Fig. 3 Phosphate Concentrations from Kinetic study on PAO seeding reactor.

In conclusion, PAOs can indeed be found in a wastewater treatment plant local to the Auburn area. Further kinetic studies will now be done to verify preliminary testing, and pending significant results, the seeding reactor will be used to provide PAOs for future experiments to observe the relationship between these valuable microorganisms and Algal Photosynthate.

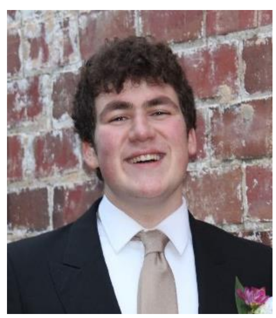
Statement of Research Advisor

Understanding how algae interact with polyphosphate accumulating organisms (PAO) is critical to designing photosynthetically-powered biological phosphorus removal systems. Optimizing such systems can improve wastewater treatment while reducing energy and greenhouse gas emissions. Justus's research project resulted in the setup of a PAO reactor in our laboratory that has been operating nearly continuously for nearly six months. This is an important first step to developing replicated continuous PAO reactors.
- *Dr. Brendan Higgins*, *Department of Biosystems Engineering*

Reference

[1] A.Y.A. Mohamed, L. Welles, A. Siggins, M.G. Healy, D. Brdjanovic, A.M. Rada-Ariza, C.M. Lopez-Vazquez, "Effects of substrate stress and light intensity on enhanced biological phosphorus removal in a photo-activated sludge system," Water Research, Volume 189 (2021)

Authors Biography



Justus Smith is a sophomore year student pursuing a B.S. degree in Biosystems Engineering at Auburn University. He has played key research roles in the culturing of specific heterotrophic bacteria from a local wastewater treatment plant for further experiments on wastewater remediation.

Qichen Wang is a post-doctoral researcher in the Department of Biosystems Engineering. His research is about developing biological processes for nutrients and carbon recycling from wastewater. Qichen received his first bachelor's degree in Food Engineering at Dalian Ocean University. He received his second bachelor's degree in Biology and his master's degree in Marine conservation and policy at Stony Brook University. He received his Ph.D. in Biosystems Engineering at Auburn University.

Dr. Brendan Higgins is an Assistant Professor in the Department of Biosystems Engineering at Auburn University. His research encompasses applications in bioenergy, waste remediation, water quality, and production of high-value nutra-ceuticals. He continues to study combined algal-bacterial processes with a particular focus on mechanisms of interaction.