Executive Summary

Inhibiting Methanogens and Homoacetogens to Enhance Hydrogen Production in Microbial Electrolysis Cells (MECs)

By Mikihiko Kurimura

PSM in Environmental Sciences, Oregon State University

August 2021

In the United States, state and local governments, and facility operators, working in the wastewater treatment section, have prioritized energy efficiency to decrease energy costs and develop environmental performance (U.S Department of Energy). This is due to population growth requiring additional energy and meeting stricter water quality requirements (Teklehaimanot et al, 2015). Specifically, municipal wastewater treatment plants across the country are estimated to consume higher than 30 terawatt hours of electricity annually (U.S Department of Energy), most usually based on traditional fossil fuel sources. As a result, the treatment plants emit significant amounts of greenhouse gases from the treatment processes, such as carbon dioxide, methane, and nitrous oxide (Campos et.al, 2016). This also relates to indirect discharge from energy production for the plants' operations. On the other hand, wastewater contains substantial amounts of chemical, thermal, and hydrodynamic energy, which could be converted to other substances (Hite, 2019). These substances can be transformed and further utilized for energy generation for industrial activities. Therefore, effective utilization of the internal energy could result in support for wastewater treatment.

For my Professional Science Master's (PSM) degree in environmental sciences internship, I opted to study a potential wastewater treatment method called Microbial Electrolysis Cells (MECs), which could potentially clean wastewater by reducing biological oxygen demand (BOD) (Trujillo, 2017). In addition, MECs generate byproducts such as hydrogen and methane from biochemical reactions (Ziara et.al, 2018) which could potentially serve as a fuel source to power the wastewater treatment process, resulting in a closed loop technology (Zhang, et.al, 2014).

I interned with Dr. Hong Liu at Oregon State University in Corvallis, OR to help investigate a new method developed in Dr. Liu's lab on inhibiting methanogenesis and homoacetogenesis in MECs to increase hydrogen production. Additionally, I supported the regular maintenance of MECs by preparing medium solutions and purging them with nitrogen, as well as measuring biogas volumes and the gas concentration by using a gas tight gradual cylinder (Image 1) and Gas Chromatography (Image 2).

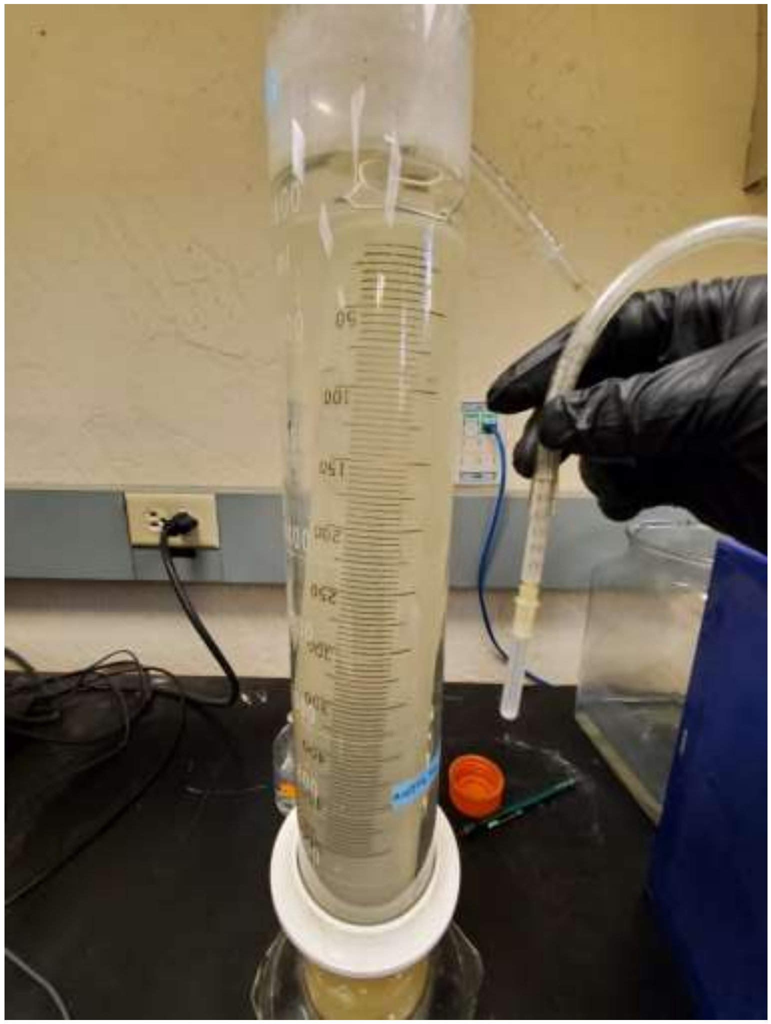

Image 1. A gas-tight gradual cylinder

Image 2. Gas Chromatography

For the science portion of the internship project, I tested the new MECs method to cease methanogens and homoacetogens which inhibit hydrogen production. These anerobic bacteria are hydrogen scavengers, causing low hydrogen volumes and inhibit cathodic hydrogen recovery. In small-scale MECs (300mL) (Image 3), the new method inhibited methanogenesis, increasing maximum hydrogen volumes for oxygen and chlorine cells from 274mL to 1160mL. It also enhanced the maximum cathodic hydrogen recovery from 65% to 114%.

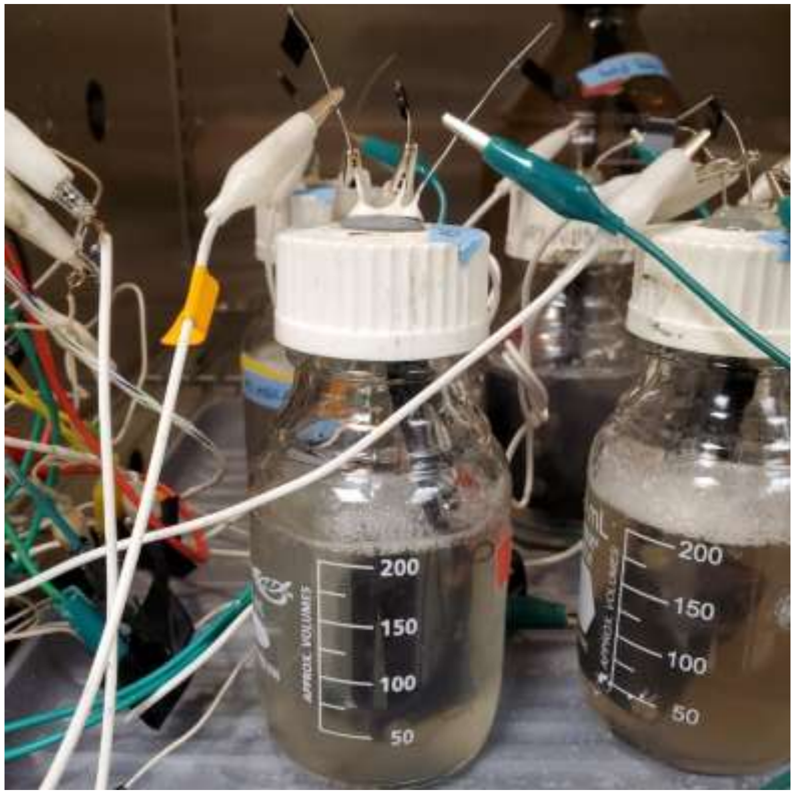

Image 3. MECs reactors (300mL)

Similarly, the method ceased homoacetogenesis, raising the maximum hydrogen volume from 181mL to 1060mL, and enhancing cathodic hydrogen recovery from 0% to 110%. In addition, the overall current densities didn't substantially change. However, in glucose-fed cells, the method caused a significant reduction in current densities and hydrogen volumes possibly due to acetate depletion from the fermentative pathway. In summary, the method could be an effective inhibitor of hydrogen scavengers and enhance hydrogen yield.

For the business portion of the internship project, I chose to create a business prospect to market MECs. Due to human population growth and related activities causing increased emissions of greenhouse gases, it is prospected that the number of days with temperatures higher than 86 degrees in Oregon areas increase by 30 days a year by mid-century (Floyd, 2019). Therefore, reducing greenhouse gas emissions needs to be considered at the local level to mitigate the large-scale changes. In Corvallis, OR, one wastewater treatment plant currently handles the load for the city of around 60,000 inhabitants, and it is managed by the public works department of the City of Corvallis. I assume that I am for the business perspective that I am marketing MEC and negotiate with the manager of the public works department while working at Dr. Liu's lab in Oregon State University. The business report includes marketing, finances, management and human resources for MECs supply as well as a partial cost analysis of MECs materials for future implementation.

For my internship project and degree requirements, I contributed to the development of MECs through the regular maintenance and further testing of this newly developed method for inhibiting hydrogen scavengers. Currently, only one method of homoacetogen inhibition has been reported. Therefore, the creation of alternative methods and further investigation of their effectiveness are crucial. In the science report, the new method showed significant impact on methanogensis and homoacetogenesis inhibition. Even though it caused substantial reduction of current densities in glucose-fed cells, the application of the method could potentially maintain the energy output and enhance hydrogen production through further experiments.

Lastely, throughout the internship project, I familiarized myself with wastewater treatment technologies, gained knowledge of organic chemistry and specifically biogas production and learned of the importance of effective utilization and reuse of wastewater. I hope to share and expand my knowledge in the field of environmental consulting in the near future.

References

Mark Floyd. (2019). Climate Report: Warming Taking its Toll on Oregon (2019). Oregon State University.

Energy Data Management Manual for the Wastewater Treatment Sector. Better Building. U.S. Department of Energy, 2.

Giorgis Z Teklehaimanot., I Kamika, M A A Coetzee., M N B Momba. (2015). Population Growth and Its Impact on the Design Capacity and Performance of the Wastewater Treatment Plant in Sedibeng and Soshanguve, South Africa. Environ Manage. 56(4): 984-97.

J.L.Campos., D. Velenzuela-Heredia, A.Pedrouso, A.Val del Rio, M. Belmonte, and A. Mosquera-Corral. (2016). Greenhouse Gases Emissions from Wastewater Treatment Plants: Minimization, Treatment, and Prevention. Journal of Chemistry. Hindawi.

Rami M.M. Ziara, Bruce I. Dvorak, Jeyamkondan Subbiah. (2018). Sustainable Waste-to-Energy Technologies: Bioelectrochemical Systems. Academic Press, 114-140.

Robert W. Hite. (2019). Moving from a “Solution” to “the Best Solution” A 21th Century Pitch to Make Permit Compliance a Byproduct of Efficient Resource Management and Recovery. 2019 VWEA Education Seminar Pulling Common Threads: The Water-Nutrient-Energy Nexus.

Stephanie, Trujillo. (2017). Using Acetylene as a Low-Cost and Effective Methanogenesis Inhibitor in Single Chamber Microbial Electrolysis Cells. Oregon State University.

Yifeng, Zhang., & Irini, Angelidaki. (2014). Microbial Electrolysis Cells Turning to Be Versatile Technology: Recent Advances and Future Challenges. Water Research, Volume 56, 11-25