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RAISE Project: Green Water Remediation for Estrogen Contaminated Agricultural Runoff

E. Navarrete, H. Shirley, E. Thorton, B. Abreha, A. Schwarzweller, A. Berman, S. Burchett, J. Choy, J. Fiorilla, V. Lykourinou

Opportunity

Agrochemicals, including the growth hormone estrogen, are used in animal production to increase yield. These chemicals are excreted as waste and carried to downstream ecosystems through runoff water. The presence of these chemicals has demonstrated detrimental effects on fish populations worldwide. Fish populations are collapsing due to the feminization of male fish, preventing reproduction and reducing population growth.

The goal of the project is to design and implement an electrochemical remediation cell that utilizes the green catalyst Fe-TAML. Hydrogen peroxide is synthesized by the electrochemical cell via a redox reaction with water. Fe-TAML and hydrogen peroxide bond to create an active complex.

This reaction enables the catalyst to oxidize estrogen and other organic compounds until they are no longer harmful. The catalyst must be held in place by a resin to prevent it from being washed away with the water. The resin must also not inhibit the catalyst from completing the reaction.

Approach

<u>Electrochemical cell to activate Fe-TAML</u>

- Hydrogen peroxide is synthesized by an electrochemical cell, via a redox reaction with water. It then activates Fe-TAML by binding to the iron core.

<u>Fe-TAML chemical breakdown of estrogen</u>

- Fe-TAML and hydrogen peroxide generate active catalyst to decompose estrogen until it is inactive.

<u>Resin in water filter</u>

- Fe-TAML will be encapsulated in a polymer medium, which will render the catalyst reusable.
- This polymer medium, a resin, will be chosen through a degradation reaction experiment. The results of this experiment are shown in Figures 4-6.

<u>Degradation of dye</u>

- Methylene blue acts as a model substrate of estrogen, as its degradation causes a visible color change; observation of the degradation is used to find the optimal combination of catalyst and resin.
- It is not similar in structure to estrogen but it is convenient, safer, and more sustainable to use in testing.

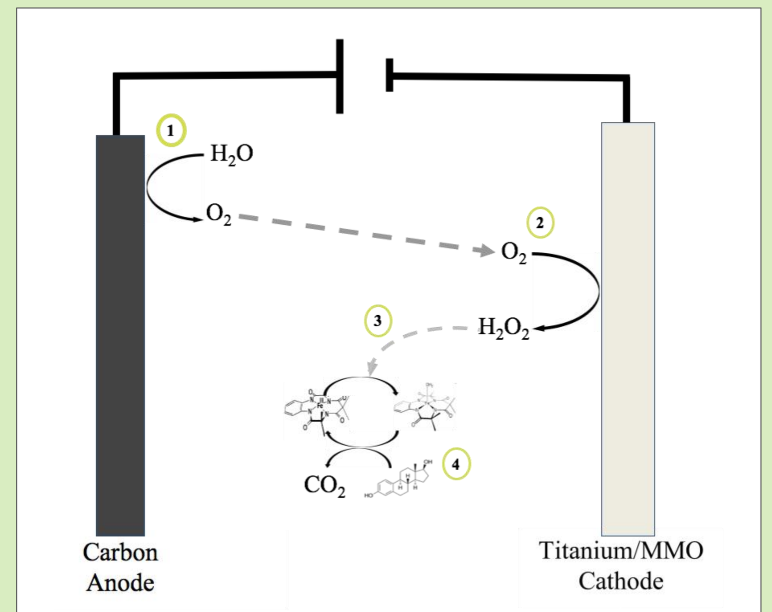

Figure 1: Degradation of estrogen in electrochemical cell

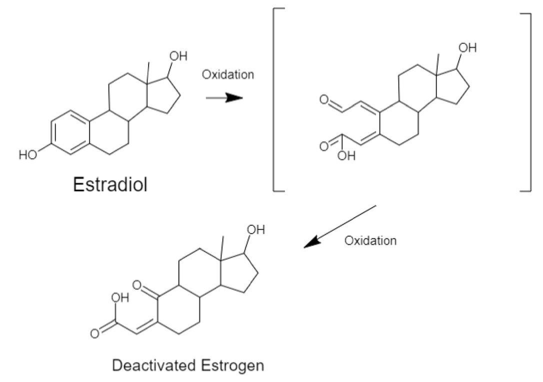

Figure 2: Breakdown of estrogen, repeated oxidation will yield CO_2

Results

Figure 3: Liquid Chromatography Mass Spectrometry (LCMS) data for Ethinylestradiol (EE2), a synthetic estrogen, degradation in the absence and presence of Fe-TAML (Figures 3.1 and 3.2).
These figures compare EE2 degradation in the presence of Fe-TAML encapsulated into the polymer Resin 2 (2-amino-ethylamine).

Top figure (3.1): No catalyst present. Only resin.
Middle figure (3.2): No resin present. Only catalyst in solution.
Bottom figure (3.3): Catalyst-resin complex.

This data shows that the catalysis occured in the catalyst solution as well as in the resin-catalyst complex. When the catalyst is in the resin, it is still active.

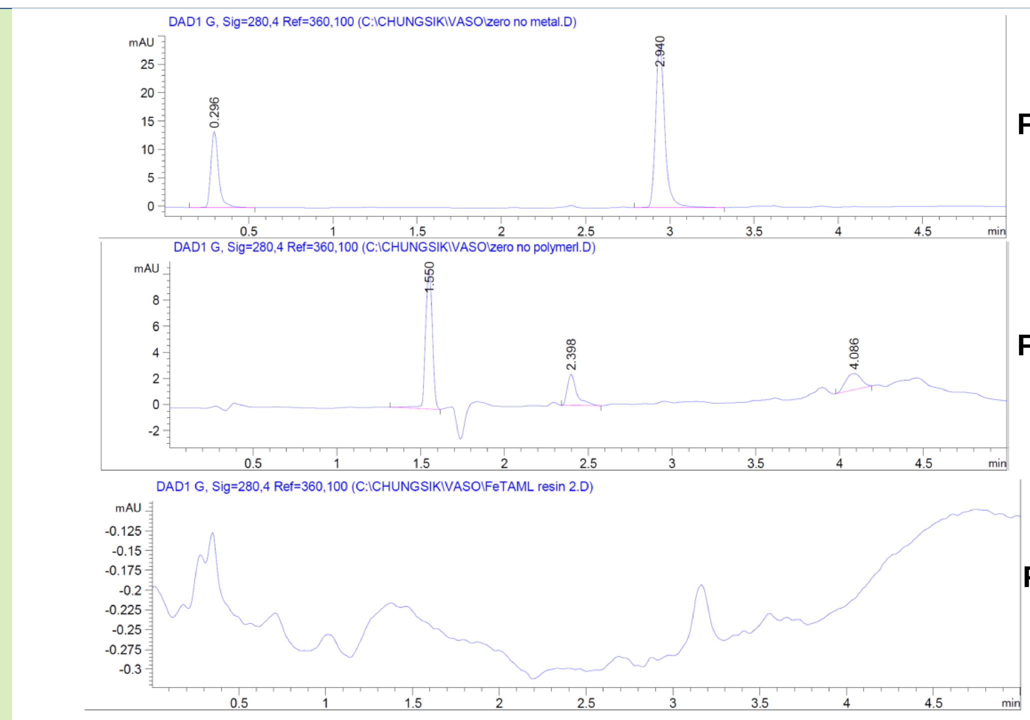

Figure 3.1

Figure 3.2

Figure 3.3

Figure 4

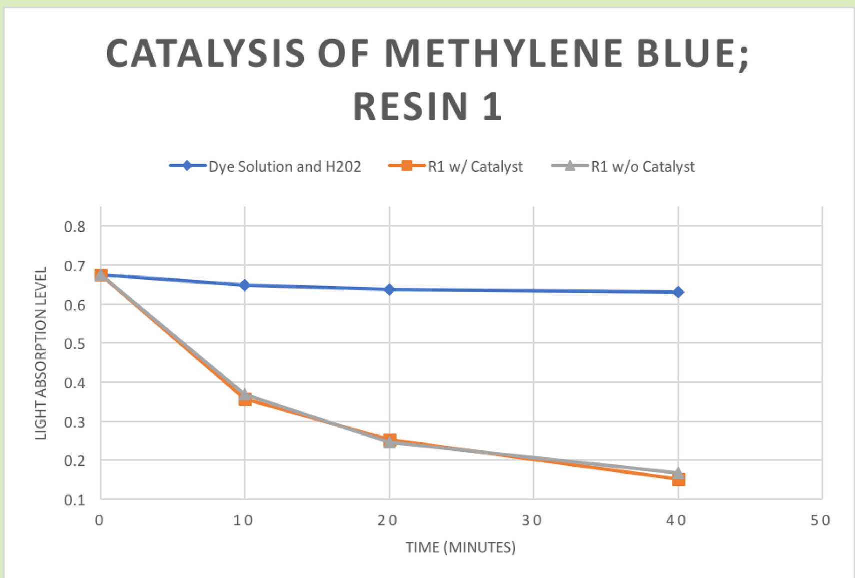

Figure 5

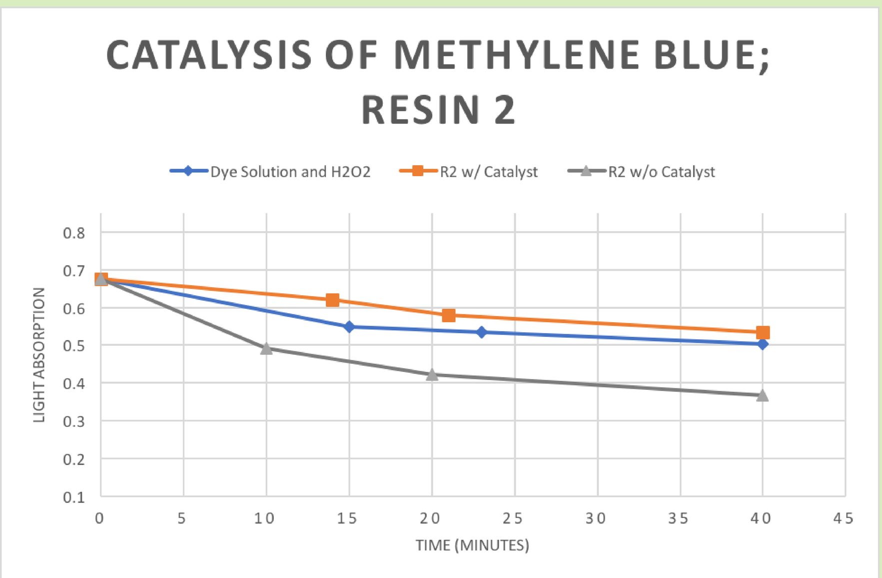

Figure 6

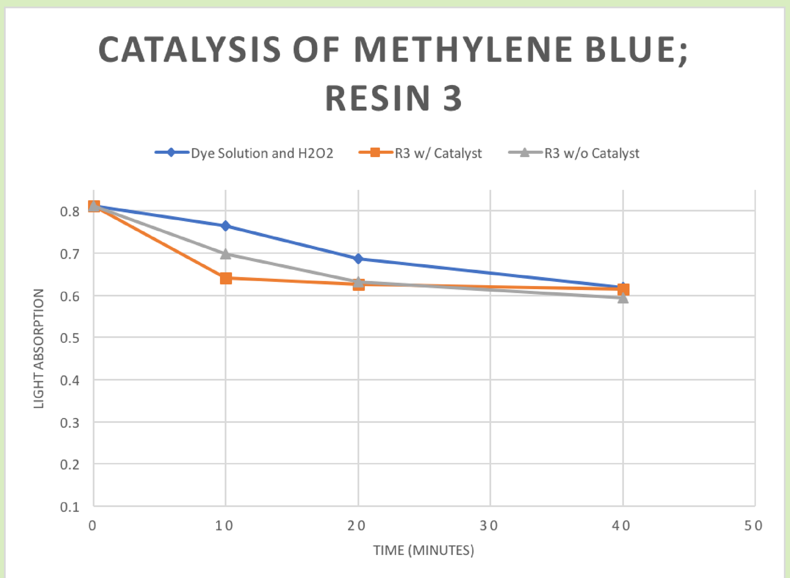

Figure 4-6: The dye methylene blue was used in place of estrogen as a mock substrate for the reaction with Fe-TAML and hydrogen peroxide. This indicates that Resin 1 (Chelex) is most active in the degradation of the dye.

Impact

The data verifies that Fe-TAML is a viable catalyst for the breakdown of estrogen. Furthermore, it was found that when resin 1 uptakes Fe-TAML, the degradation rate is not compromised. Therefore, resin 1 is the ideal resin as of right now because it was the most active in the degradation reaction (Figures 4-6).

In this project, we are developing a solar-powered electrochemical cell to break down estrogen. The catalyst will be regenerated and the hydrogen peroxide continuously produced, resulting in a sustainable and low maintenance system. Because of this, the system can be an efficient and long term solution to water contamination.

We will continue to characterize the catalyst and determine how many cycles of degradation the estrogen must undergo to be inactive, and the durability of the heterogeneous system. We will also develop a filter to optimize water-resin contact.