Project #2: Photoelectrochemical reactors for environmental remediation

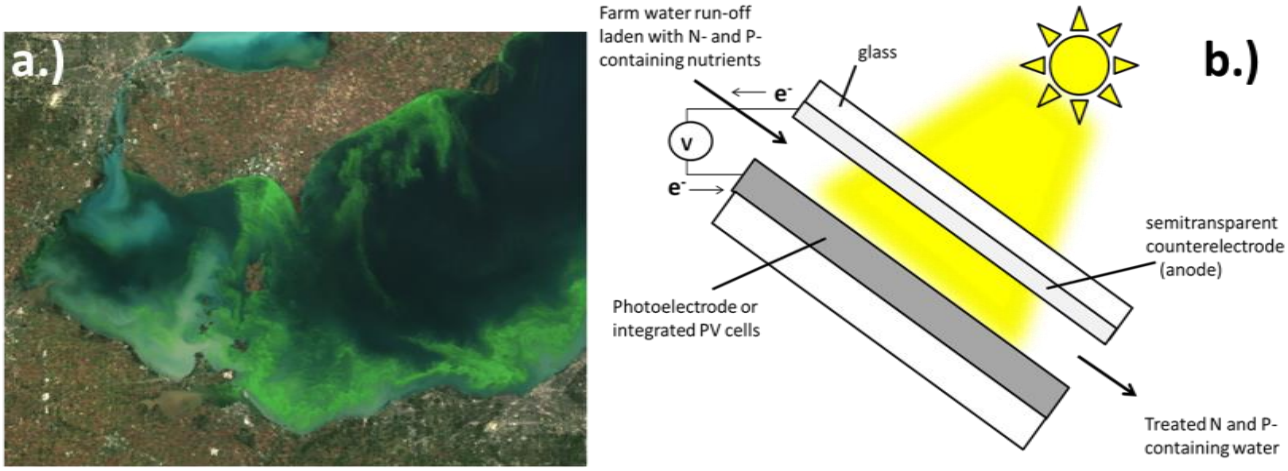

Figure: *a.) Algae blooms in Lake Erie (AP Photo courtesy of NOAA). b.) Solar reactor for treatment of nutrient-laden water that has run-off from fields.*

Scenario: Fertilizer has enabled farmers to feed billions around the world, but its mismanagement often results in significant amounts of unutilized fertilizer being washed off with rain into streams, rivers, and eventually larger bodies of water. This "run off" of unutilized fertilizer has serious environmental consequences. In addition to creating concerns for safe drinking water, the unused nitrogen- and phosphorous-containing molecules can initiate runaway algae blooms in major waterways such as Lake Erie (Fig. a) and the Gulf of Mexico.[1] These blooms can deaerate the water, suffocating local aquatic life and creating biological dead zones.

For this assignment, your task is to evaluate the viability of treating agricultural runoff using a photoelectrochemical or PV-electrolysis reactor that degrades the nutrients to a benign form (or convert them to high energy, storable products) before returning the treated water to the environment. Runoff water would be fed through a reactor based on a parallel plate design (Figure b). The bottom plate would contain the photoelectrode while the top plate would consist of a glass window and a semitransparent counter electrode. This flow-by electrode design is particularly advantageous when the rate of mass transfer is limited by low concentrations of reactant. Product species from each electrode would be separated downstream.

In order to arrive at your final recommendation, you should address the following:

(i) Describe the (photo)electrochemistry. What reactions will take place on the anode and cathode of the (photo)electrochemical reactor? What voltage must be applied across electrodes?

(ii.) Assuming that the reactor is a flat plate design, what are the operating conditions? Do you expect that the reaction rate will be limited by mass transfer, kinetics, or light under these conditions? What is your target conversion and throughput, and what reactor size would achieve these goals? How much reactor area is required per acre of farm land? Include a flow diagram that clearly shows the major components of your set-up.

(iii.) For three different locations in the U.S. (different levels of solar irradiance and rain fall from TMY data), what is the estimated cost per acre to perform this treatment? How much cost would this add to the price of a bushel of corn or other common crop?

References

[1] http://www.huffingtonpost.com/2014/08/04/lake-erie-algae-bloom-2014-_n_5647824.html

[2] http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1045480.pdf

[3] http://www.desmoinesregister.com/story/money/agriculture/2015/09/13/tiling-pollution-nitrates/72103422/