Electrochemical Sensor for Detection of Phosphorus in Stormwater

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Abstract

Phosphorus is one of the main elements behind the process of eutrophication, which hurts the aquatic life in any body of water. Unfortunately, the current methods we have of detecting phosphorus in stormwater requires expensive equipment and is time consuming. The main purpose of this research is to evaluate the performance of an electrochemical sensor for detection of phosphorus in stormwater. This electrochemical phosphate sensor was made from cobalt oxide nanoparticles by drop-casting[1] method that was previously used to test for phosphorus in drinking water.

Introduction

Eutrophication occurs when there is an excessive amount of nutrients in a lake or any body of water, that usually comes from land runoff, which causes the algae to grow at an exponential rate.[2] With the large amount of algae growth that is occurring in the water the aquatic life dies off due to lack of oxygen. This nutrient pollution has become a problem not only for the habitats it has destroyed but for humans as well. The water not only becomes uninhabitable for the aquatic life, but it also becomes a danger to humans because the water could become toxic if left untreated. So, eutrophication is high on the list of priorities especially for freshwater lakes because states like Wisconsin often use the lake water for drinking.[3] The main problem our state is faced with as of right now is how can they tell how much phosphate is in the runoff produced by farms. As of right now the only effective method is to take a sample from the farm to a lab and analyze it using a UV Spectrometer[2][3] While that is an effective way of measuring phosphorus in each sample, it takes a while to do and UV spectrometers are not cheap. That is what this phosphate sensor tries to duplicate, a way of measuring phosphorus in stormwater without all the extra steps and machinery. The sensor has been used before to test phosphorus levels in drinking water[4], but for this research project the goals is to see if this sensor can also be used in stormwater runoff.

The research questions that need to be addressed are:

- Does the sensor differentiate between lower levels of Stock P solution versus higher levels?
- Does the sensor show any readings with a stormwater sample with an unknown concentration of phosphorus?
- Does the sensor accurately predict the concentration of phosphorus from the stormwater sample?
- How many times can one sensor be used to conduct this test?

Methodology

To better visualize the process a flowchart has been put together:

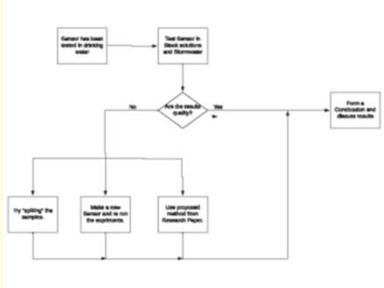

Figure 1: Flowchart for process of testing sensor.

EPA Method 5.1 for determination of Concentration of Phosphorus:

- The first step in making the known concentration of Phosphorous solution is to make a stock solution of 100mg/L. We first take the compound KH_2PO_4 as source of phosphorous.
- Next, the appropriate amount of KH_2PO_4 is measured out to achieve the 100mg/L concentration. Then transfer the weighted Phosphorus to a 1L volumetric flask. Next, 1L of E-pure water is poured into the flask and invert several time to make sure it is a homogenous mixture.
- The stock solution should not be used for the test, but instead dilute solutions should be made from the stock solutions. The preparation for the dilution are as follows: make sure the volumetric flask is cleaned with DI water, use five 100ml volumetric flask to dilute the stock solution to a working standard.
- Next using a 100-1000μL pipette with the epT.I.P.S 50-1000μL tip, cleaned with a kimwipe and ethanol, extract exactly 0.005 ml of solution from the stock solution and transfer this solution to the 100ml volumetric flask. Pour E-pure water to just below meniscus line then use a bulb pipette to fill flask to the meniscus line, making sure the bottom the Semi-sphere should coincide the meniscus line. For the remaining 4 flasks repeat the same steps except change the amount of stock solution to .1, 0.5, 0.01, 0.05 mg P/L for each flask respectively.

Measuring phosphorus concentration using a novel Electrochemical Sensor:

1. The first thing that must be done when testing the sensor is to dip it in in DI water for about 2-3 minutes and dry it off without touching the center
2. Connect the sensor to the electrodes(Figure 2) and turn on the analyzer(Figure 3).
3. Open Circuit Voltammetry, Run time: 400 s, Sample interval: 0.1 s
4. Prepare cuvettes with concentrations of the P solution from low to high concentration.

Figure 2: Three-electrode Detection

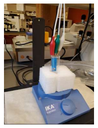

Figure 3: Electrical potential reading

Preliminary Results

The first round of testing the sensor yielded these two graphs of potential voltage over time:

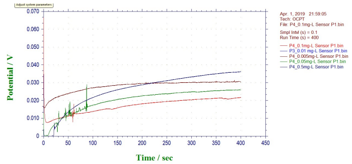

Figure 4: Readings from Sensor P1 plotted at Potential Voltage over Time

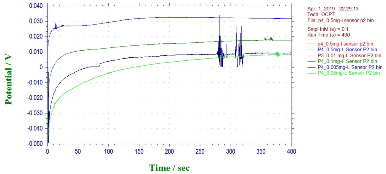

Figure 5: Readings from sensor P3 plotted at Potential Voltage over Time

Discussion

From these initial tests two of the proposed scientific questions can be answered and predict the outcome for future tests. The sensor was able to differentiate between various concentrations of P solution and gave a different reading for each. This procedure was performed successfully in duplicate. One conclusion that can be withdrawn is that the sensor has a hard time getting a consistent reading from high concentrations of phosphorus. There should be able to find a yield point at which the sensor will stop giving an accurate reading. Also, there must be verification through the SRP method of testing that each standard is as accurate as possible. The next step in the experiments is to measure P concentration on stormwater samples both methods- standard and novel sensor - and see if the readings agree.

Conclusion

- Initial results indicate that each concentration of P solution gives a different reading.
- The sensors were not calibrated so that is why there are some skews in the graphs (Figure 4-5).

Literature cited

[1] L. Zhu, X. Zhou, H. Shi, Front. Environ. Sci. Eng. 2014, 8(6), 945-951.

[2]"Sources and Solutions: Stormwater." EPA, Environmental Protection Agency, 15 Apr. 2019, www.epa.gov/nutrientpollution/sources-and-solutions-stormwater.

[3]"Causes, Effects and Solutions to Eutrophication." Conserve Energy Future, 15 Jan. 2017, www.conserve-energy-future.com/causes-effects-and-solutions-to-eutrophication.php#:~:text=.

[4]Yang, J., Kwak, T.-J., Zhang, X., McClain, R., Chang, W.-J., & Gunasekaran, S. (2016, November 22)

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For further information

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