A Low Cost Chemosensor for Measuring Phosphate in Water and Soil

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Washington, DC | U.S. EPA SBIR Phase I Kick-Off Meeting | April 5–6, 2007

Problem Statement

In many areas, the rapid growth and intensification of crop and animal farming, including confined animal feeding operations (CAFOs), has created regional and local imbalances in phosphorus (P) inputs and outputs. When phosphorus is released into water bodies with adequate nitrogen available eutrophication is likely to result. Eutrophication has been identified as the main cause of impaired surface water quality in the U.S. Concentrations of phosphate in solution are usually small, and time is often a critical factor in taking measurements since the inorganic phosphate in a water sample is changing due to biological processes. Due to these factors, there is a need for sensitive, inexpensive, and portable instruments in order to monitor the eutrophication process effectively. Currently available instruments for making phosphate measurements in the field do not adequately address these needs.

Figure 1. *CAFO lagoon overflow (adapted from www.factoryfarm.org).*

Figure 2. *Ion chromatography system. Ion chromatography and other instrumentation used for phosphate measurements requires reagents and often is not portable (adapted from www.caer.uky.edu).*

Technology Description

The sensor that is being developed in this Phase I research is based on a commercially available microfabricated fringing electric field (FEF) substrate (Figures 3 and 5) coated with the phosphate-binding polymer that incorporates highly selective pseudo-tetrahedron cleft molecules (Figure 4). The substrate electrode periodicity is in the low microns range. By incorporating nanofabrication techniques in the Phase II portion of this research, it will be possible to design and fabricate smaller electrode structures. This will allow us to enhance the sensitivity of the sensor system by tuning the electric field pattern generated by FEF sensor to the dimensions of the thin film phosphate-binding polymer coatings.

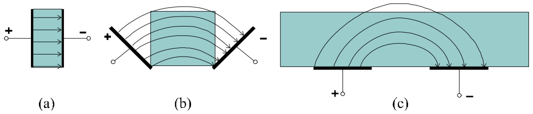

Figure 3. *A fringing field dielectrometry sensor visualized as a parallel-plate capacitor (a) whose electrodes open up (b) to provide a one-sided access to the material being tested (c) (adapted from A.V. Mamishev et al., Proceedings of the IEEE, 2004).*

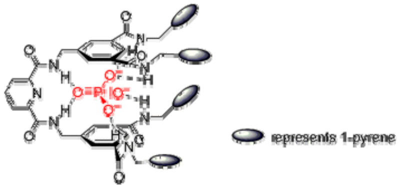

Figure 4. *The neutral receptor that provides a pseudo-tetrahedron cleft to allow highly selective complexation with phosphate ion (adapted from J. H. Liao et al., Organic Letters, 2002).*

Expected Results

The key result needed to support the development of a prototype instrument will be the demonstration of binding selectivity for phosphate. A chemosensor, to be developed on the basis of this selectivity, would be relatively inexpensive, would require no chemical reagents, and could easily be installed in the field for continuous and/or remote monitoring applications. It would be a valuable tool which could aid researchers, CAFOs, and farmers in the development of improved phosphorus management practices through an interdisciplinary effort involving soil scientists, hydrologists, agronomists, limnologists, and animal scientists.

The handheld phosphate analyzer that will be developed in this project significantly reduces the cost of performing routine field phosphate measurements. The estimated cost of manufacturing the analyzer would be under $1,000. The instrument will not require reagents or any other consumables eliminating costs and environmental issues associated with the disposal of the testing materials. The portable phosphate analyzer that will be developed in this project will allow fast, safe, and easy measurements of the environmental phosphate concentrations.

By modifying the chemistry of the polymer coating, the FEF sensor technology to be demonstrated in this research could be adapted to other analytes of environmental interest including lead, arsenic, and other metals and nutrients.

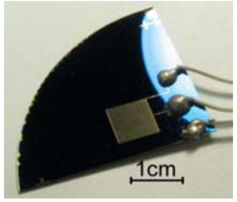

Figure 5. *A microfabricated fringing electric field sensor substrate will be a key to developing a low cost phosphate analyzer.*

Potential Environmental Benefits

The low cost portable instrument which we propose to develop in this research will support efforts to cost effectively address the problems associated with increased levels of phosphate in surface waters resulting from agricultural practices including confined animal feeding operations. Phosphorus management strategies cannot be universally applied. Phosphorus management is very site specific and requires a well-planned, coordinated effort among animal feeding operations, farmers, agronomists, and soil conservation specialists (A.N. Sharpley et al., ARS-149, 2003). Overall management systems for reducing losses from agriculture activities should be to balance phosphorus inputs in feed and fertilizer with outputs of phosphorus in products at both farm and watershed scales and to manage soils in ways that retain crop nutrient resources. Each site and each water body are different with respect to their vulnerability to phosphorus release. Management plans for phosphorus and best management practices must be tailored to site vulnerability to phosphorus loss and proximity of phosphorus sensitive waters.

The proposed technology offers additional benefits by helping to limit the degradation of lakes and rivers from eutrophication stimulated by phosphorus releases from agricultural activities. It will also help to conserve phosphorus for crop production, since in many areas of the world, phosphorus is becoming a scarce resource.

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This research is funded by USEPA SBIR Program, Contract # EP-D-07-048