The Exploratory Advanced Research Program Fact Sheet

Remotely Monitoring Water Quality Near Highways

A Sustainable Solution

Exploratory Advanced Research . . . Next Generation Transportation Solutions

Collecting water quality data on streams located near highways can be challenging in remote and difficult-to-reach locations. Obtaining and transporting water samples is time-consuming, expensive, and sometimes dangerous. Another key challenge is that transportation agencies can miss the release of toxins and pollutants that occur in a short time period or the first flush of stormwater runoff from highways. Collecting water quality data is crucial, however, to State departments of transportation in their effort to meet U.S. Environmental Protection Agency National Pollutant Discharge Elimination System permit requirements, particularly during the first flushes of spring stormwater runoff.

Placing sensors directly in the water to collect data is an appealing solution, but these in situ sensors typically rely on batteries that have to be replaced as often as every 3 weeks. Designing a renewable and self-sustaining onsite system is the goal of the Exploratory Advanced Research (EAR) Program project "A Remote, Self-Sustained System for Monitoring Water Quality Near Highways." Montana State University conducted this research, which was funded by the Federal Highway Administration (FHWA).

A Self-Sustained Sensing System

The innovation of this project's research is that it combines the remote monitoring capabilities of in situ sensors with renewable and self-sustaining bio-energy generation. Instead of batteries, the wireless sensors are powered by microbial fuel cells (MFC) that generate electricity through electrochemical reactions with a type of common and safe bacteria (magnesium oxidizing microorganisms) ubiquitous to streams. Researchers designed MFCs that can essentially function as batteries when there is little microbial activity in the stream but operate as MFCs when significant microbial activity occurs. These MFCs differ from traditional ones that tend to have low energy generation and limited scalability. Because the energy generated from MFCs can fluctuate, a power management system regulates the voltage to provide a stable and accurate direct current voltage that can power the sensors and support a control system that collects, processes, and transmits the real-time water quality data.

Field Tests

Project researchers first tested the MFC in their laboratory at Montana State University. After placing the MFC into a plastic tank filled with harvested pond water, researchers connected it to a varied resistive electrical load. After several months of laboratory tests, researchers conducted a 5-week field test in a stream located at the intersection of 11th Avenue and Opportunity Drive in Bozeman, MT. During the test, the researchers investigated the stability of the MFC's power output and recorded the output voltages three times a day. To increase the amount of energy provided by the MFC, project staff redesigned the power management and sensor network systems after the initial field test so that harvested energy would be used more efficiently. Researchers then conducted a 3-month test of the entire system, including a waterproof floating sensor enclosure, in the same stream. A device that could float was key to the sensors' successful operation, as the wireless signals cannot penetrate water.

U.S. Department of Transportation
Federal Highway Administration

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Microbial fuel cells power in situ sensors to remotely monitor water quality. The fuel cells generate electricity through electrochemical reactions with a type of bacteria ubiquitous to streams.

Key Findings

Among the key findings resulting from the field test is that environmental conditions, including water flow rate, pH, temperature, dissolved oxygen concentration, and chloride concentration, were significant factors affecting the MFC's power output. The MFC required 4 to 6 hours to harvest enough energy to boost the energy management circuit. This energy was collected by the power management system, which then released enough power in short but sufficient periods for the sensors and communication devices to operate. The output power voltage generated by the MFC remained stable during the field testing. Overall, the sensing system continuously provided water quality data during the testing, including pH, temperature, and chloride levels. Data frequency ranged from four to seven samples a day.

Future Work

The project researchers successfully demonstrated the concept of using MFCs as a self-sustainable power supply to collect remote water quality data. Future work is needed to enhance the capability, performance, reliability, and cost-effectiveness of the technology and make it market-ready. In particular, improvements are needed to increase the energy output of the MFCs and integrate acoustic communication modules into the sensors to increase the wireless communication range. At present, the communication range is limited because the signals cannot penetrate water. Other issues to address in future work are the feasibility of protecting the system from wildlife and severe weather conditions.

Importance to FHWA

The proposed system would extend the operational time of sensors deployed in streams and result in significant benefits, including reduced maintenance costs and increased safety for State transportation agency staff involved in water quality monitoring. As agencies contend with limited budgets, being able to remotely monitor targeted streams means that staff experts can avoid spending considerable time conducting routine and repetitive tasks in the field. The end result is that agencies can improve their operational efficiency while still meeting crucial environmental protection and water quality needs.

Learn More

For more information on this project, contact Marcel Tchaou in the FHWA Office of Project Development and Environmental Review, 202-366-4196 (email: marcel.tchaou@dot.gov).

EXPLORATORY ADVANCED **RESEARCH**

What Is the Exploratory Advanced Research Program?

FHWA's Exploratory Advanced Research (EAR) Program focuses on longer term, higher risk research with a high payoff potential. The program addresses underlying gaps faced by applied highway research programs, anticipates emerging issues with national implications, and reflects broad transportation industry goals and objectives. To learn more about the EAR Program, visit the EAR Web site at www.fhwa.dot.gov/advancedresearch. The site features information on research solicitations, updates on ongoing research, links to published materials, summaries of past EAR Program events, and details on upcoming events.

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The project's control system collects, processes, and transmits the real-time water quality data provided by the in situ sensors.

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