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Project Summary

The Feasibility of Using Fiber Optics for Monitoring Groundwater Contaminants

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This report contains the results of the initial feasibility study for a research program undertaken to develop the technology needed to use fiber optics for monitoring groundwater contaminants. The technology appears especially well suited to the requirements of detection monitoring, where a few indicator parameters can be measured continuously by sensors placed down small-diameter monitoring wells. Data are generated at a remote, centrally located fluorimeter, connected to the sampling sites by inexpensive optical fibers.

The analytical method is laser-induced fluorescence, which gives the desired sensitivity. The optrode, a chemical system and/or a mechanical device at the distal end of a fiber optic, furnishes the needed specificity. Various fiber and optrode configurations have been evaluated and their applications to groundwater monitoring are discussed. Feasibility is shown for physical measurements such as temperature, pressure, and pH. Chemical detection and quantification methods for the actinides, inorganic and organic chlorides, sulfates, alcohols, aldehydes, pesticides and tracer materials are presented.

Finally, it is shown that the need for smaller diameter wells (as compared to conventional sampling methods) and the ability to make up to 50 unattended *in situ* measurements using a reasonably priced, centralized fluorimeter system connected to the sampling sites by inexpensive optical fibers results in acceptable economy.

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This Project Summary was developed by EPA's Environmental Monitoring Systems Laboratory, Las Vegas, NV, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

When it was learned that Lawrence Livermore National Laboratories (LLNL) was developing technology to make remote measurements of pH, temperature, and various ion concentrations in hostile environments for the Department of Energy by means of laser-induced fluorescence spectroscopy over optical fibers, EPA recognized the possibility of using the technique for groundwater monitoring. The specificity, sensitivity, and remote measurement capabilities of fiber optic fluorescence spectroscopy appear to be ideally suited to EPA's needs. This report is an overview of what has been accomplished at LLNL for EPA and what is feasible using fiber optic techniques in regard to RCRA groundwater detection monitoring needs.

Results

EPA asked LLNL to consider the feasibility of monitoring six categories of groundwater pollutants. The results were as follows:

a. Inorganic chloride—Analysis is accomplished using the reaction of Cl^- with silver fluoresceinate to release the fluorescent fluorescein. Data exist to 10 ppm with projections of sub-ppm sensitivities.

b. Organic chloride—A general analytical method based on the complete oxidation of organic chloride by chromic oxide to yield Cl^- and the subsequent reaction with silver fluoresceinate is being developed. At present, only the two individual reactions have been successfully tested. Detection limits appear to be dependent on the AgCl solubility.

c. Aldehydes—Measurement is accomplished by the quenching of normally fluorescent Schiff reagents by aldehydes.

d. Alcohols—Selective oxidation of alcohols to aldehydes is accomplished and then the degree of quenching of Schiff reagents is determined.

e. Sulfate—The release of fluorescent chloranilic acid from barium chloranilate by the reaction with $SO_4^=$ is the chosen analytical method.

f. Pesticides—An initial effort indicated that an enzymatic reaction based on cholinesterase inhibition by pesticides is a good detection method. The complexity of the approach makes it subject to re-evaluation.

Measurement techniques for other parameters are also presented.

The use of tracers in groundwater is important both for research purposes and for following the route of contamination for specific injection sources. In this study, fiber optic detection of fluorescent tracers such as Rhodamine 6G, brilliant sulphoflavine, and fluorescein was evaluated at concentrations of 1 part-per-million and a fiber length of 100 meters. Extrapolation of the data indicates that at 300 meters, detection limits could reach 1 part-per-billion or less.

Temperature, pressure, pH, and Eh (oxidation potential) have also been measured. These measurements are important because they give information about the contaminant species which is present. Temperature can be measured over a wide range to 0.1°C and over a restricted span to 0.01°C from 20 to 250°C. Pressure can be resolved to 0.01 PSI, and pH is resolvable to 0.05 pH units over the complete pH scale. Eh can be determined to 0.1 V from 1.1 to -0.6 V. Methods for pH and Eh are presently being further developed.

Conclusions

Results of the feasibility study show that remote fiber fluorimetry is well suited to the requirements of groundwater detection monitoring. This approach has the potential of qualifying and quantifying groundwater contaminants in the sub-parts-per-million (ppm) range. Tracer materials can be detected below one part-per-billion (ppb). In addition, measurements can be made of the physical properties of groundwater which affect contamination. Finally, a preliminary economic study indicates that this method may be less expensive than extant monitoring techniques.

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The complete report, entitled "The Feasibility of Using Fiber Optics for Monitoring Groundwater Contaminants," (Order No. PB 84-201 607; Cost: $11.50, subject to change) will be available only from:

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