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The instrumentation this grant has allowed us to purchase has greatly enhanced our research program in environmental engineering and science. We can now address, in a much broader way, the control of hazardous substances in the environment. The items purchased include: Gas chromatograph/Mass spectrometer/Computer system; five Bioengineering magnetic-drive chemostats with digital microprocessor controls; Polargraphic analyzer system with EG&G Polarographic detector and Coy "Type A" anaerobic chamber, and a Dionex series 40001 ion chromatograph. This equipment is shared by faculty members of the Environmental Engineering and Science Program, Department of Civil Engineering and their staff and students. A major study supported by this equipment involves laboratory and field-scale evaluation of the situ biodegradation of chlorinated solvents at Moffett Naval Air Station. The objective is to remediate chlorinated-solvent contaminated groundwater by use of methanotrophic bacteria.

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July 13, 1988

Major T. J. Cerveny
AFOSR/NL
Bolling Air Force Base
DC 20332-6448

Subject: Final Report for Grant No. AFOSR-86-0281

Dear Major Cerveny:

This is the final report for the above grant entitled, "Instrumentation for Basic Research on Chemical and Biological Processes for Hazardous Material Control." The instrumentation that this grant has allowed us to purchase has greatly enhanced our research program in environmental engineering and science. It has allowed us to address in a much broader way the control of hazardous substances in the environment, a major problem now facing the United States in general, as well as the Department of Defense. We are greatly appreciative to the U.S. Air Force for making these funds available to us.

The grant from the Air Force was for a total of $175,000. This was supplemented with $40,000 in cost-sharing funds from Stanford University, resulting in a total of $215,000 for new equipment. The items of research equipment purchased with these funds are as follows:

1. Gas Chromatograph/Mass Spectrometer/Computer System, including Hewlett-Packard Model 5890A gas chromatograph, Model 5970B Mass Spectrometer, and Monochrome Computer, together with necessary accessories.

2. Five (5) Lab-Line Bioengineering magnetic-drive chemostats with digital microprocessor controls, and accessories.

3. Polarographic Analyzer System, including EG&G Polarographic Detector and Coy "Type A" Anaerobic Chamber, plus accessories.

4. Dionex Series 4000i Ion Chromatograph and accessories (purchased with cost-sharing funds).

The above equipment is shared by the five faculty members of the Environmental Engineering and Science Program, Department of Civil Engineering, and their staff and students. This graduate research program currently has 2 technicians, a research associate, about 25 Ph.D. candidates, 4 postdoctoral scholars, and visiting faculty, essentially all conducting research associated with the movement and fate of hazardous substances, and methods for their control. The program has several research grants and contracts, with total yearly funding of about $1.5 million. Grants and contracts are from the U.S. Environmental Protection Agency, U.S. National Science Foundation, U.S. Geological survey, U.S. Department of Energy, U.S. Department of Air Force, U.S. Department of Navy, the Orange County Water District, the Shell Development Company, and the Gas Research Institute.

A major study on which most of the equipment purchased under this grant is being used is a laboratory and field-scale evaluation of in-situ biodegradation of chlorinated solvents, funded by

the U.S. EPA and conducted at the Department of Navy's Moffett Naval Air Station, Mountain View, California. The objective here is to remediate chlorinated-solvent contaminated groundwater by use of methanotrophic bacteria. These organisms use methane and oxygen as a source of energy for growth, and oxidize chlorinated solvent contaminants such as TCE, DCE, and vinyl chloride by co-metabolism. The ion chromatograph is being used to measure the inorganic components of the groundwater system, including bromide, which is injected as a tracer. The automated field monitoring system uses gas chromatography for analysis of components, and the GC/MS/Computer system is being used to confirm the identification and to quantify intermediates formed in the biological degradation of 1,2-dichloroethylene. The major intermediate formed was found to be a dichloroethane epoxide. This potentially hazardous intermediate was found to hydrolyze chemically within a short period of time. The chemostats are being used to determine coefficients describing the growth of the methanotrophs, and their rate of chlorinated solvent utilization.

In another study supported by EPA and Shell, processes causing chemical transformation of chlorinated products under anaerobic or reducing environments is being studied. Here, the gas chromatograph is again used, but in addition, the polarographic system is most important. The ion chromatograph is also being used in these studies.

Through an NSF grant, the mechanisms responsible for anaerobic biological reductions of a group of chlorinated solvents of importance in groundwater contamination is being studied. Here, the chemostats are being used in order to determine factors affecting the kinetics of the process, and ion chromatography is being used to evaluate the transformation of inorganic contaminants such as nitrate and selenium.

In other studies funded by the EPA, the USGS, and the Orange Country Water District, the potential for anaerobic biotransformation of gasoline and other petroleum products that are common ground water contaminants, is being evaluated. Aquifer samples from the Department of Navy Seal Beach facility in California, where a gasoline spill occurred, are being analyzed to determine the presence of anaerobic bacteria that are capable of biodegrading benzene, toluene, and xylene. These major water-soluble components of gasoline have been found by the Stanford group to be biodegradable by methane-producing anaerobic bacteria. Here, the GC/MS/computer system is being used on a daily basis to identify intermediates formed during biodegradation. This is a most important process because of the potential it has for natural biotransformation of contaminants in the environment.

The chemostats are being used on another project, currently supported by the Gas Research Institute, but also expected to be supported soon by the U.S. Department of Energy, that is concerned with developing a biological system for treatment of chlorinated-solvent containing waters extracted from the ground.

There are numerous other projects on which the instrumentation purchased through this equipment grant is used on occasion, and we now have several proposals submitted that would also take advantage of the instrumentation. These include a proposed center on hazardous substances, which would be supported by EPA, and further studies on biodegradation of gasoline components, that would be supported by the Department of Navy. The research activity in our laboratory has increased considerably since this equipment has become available. It has helped satisfy an important need.

We are addressing several problems of great concern currently to the Department of Defense. Contamination of soils and groundwaters with hazardous substances has occurred at a large percentage of the military facilities in the United States. Estimated costs for cleanup approach $100 billion. The problems are highly complex, and current solutions are not very promising. The

research being conducted with the equipment provided by this grant has helped substantially to increase our capabilities to address these significant problems.

I wish to thank the Air Force for its generosity in providing these funds to our program at Stanford University. They are very much appreciated.

Sincerely yours,

Perry L. McCarty