WATER RESOURCES RESEARCH GRANT PROGRAM

PROJECT DESCRIPTIONS, FISCAL YEAR 1989

Compiled by Melvin Lew and Pamela Murray

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DEPARTMENT OF THE INTERIOR

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WATER RESOURCES RESEARCH GRANT PROGRAM
PROJECT DESCRIPTIONS, FISCAL YEAR 1989

By Office of External Research
Water Resources Division
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ABSTRACT

This report contains information on the 36 new projects funded by the U.S. Geological Survey's Water Resources Research Grant Program in fiscal year 1989 and on 27 projects completed during the year. For the new projects, the report gives the grant number, project title, performing organization, principal investigator(s), project duration, and a project description that includes: (1) identification of water-related problems and problem-solution approach, (2) contribution to problem solution, (3) objectives, and (4) approach. The 36 projects include 6 in ground-water transport and flow, 4 in the water-quality treatment processes, 5 in water-quality processes, 5 in biology, 9 in economics and management, and 7 in climate and hydrology.

For the 27 completed projects, the report gives the grant number, project title, performing organization, principal investigator(s), starting date, date of receipt of final report, and an abstract of the final report. Each project description provides the information needed to obtain a copy of the final report.

The report also contains tables showing (1) proposals received according to area of research interest, (2) grant awards and funding according to area of research interest, (3) proposals received according to type of submitting organization, and (4) awards and funding according to type of organization.

INTRODUCTION

In January 1985, the U.S. Geological Survey was assigned responsibility for administering the functions of the Water Resources Research Act of 1984 (Public Law 98-242). Section 105 of the act authorizes funds for research grants, on a fund-matching basis, to qualified individuals and groups as defined in the law. Each year an announcement is issued to solicit proposals for research support from the funds appropriated by the Congress.

In fiscal year (FY) 1985, 24 of 368 proposals that were submitted were selected for funding with the $2.543 million appropriated by Congress. In FY 1986, 43 of 299 proposals were selected for funding with the $4.767 million appropriated, in FY 1987, 34 of 273 proposals were selected for funding with the $4.381 million appropriated, and in FY 1988, 38 of 239 proposals were selected for funding with the $4.381 million appropriated. These projects are described in U.S. Geological Survey Open-File Reports 85-687, 86-548, 88-179, and 89-249, respectively.

In FY 1989, 260 proposals requesting about $29.9 million of Federal funding ($31.0 million of non-Federal funding) were submitted in response to U.S. Geological Survey Announcement No. 7442 issued on August 15, 1988. Of this number, 36 were selected for funding with the $4.381 million appropriation (Table 1). As in previous years, proposals from academic institutions dominated the competition for grant funds (Table 2).

Section I of the report presents summaries of 36 proposals selected for funding. Section II presents summaries of the 27 projects completed during FY 1989.

Table 1.--Proposals and awards by research interest area, fiscal year 1989

Proposals

Interest Area	No.	Federal ($) Funds	Non-Federal Funds($)	Total Funds($)
Ground-Water Flow and Transport	34	3,751,891	3,941,565	7,693,456
Treatment Processes	43	5,210,097	5,370,914	10,581,011
Water-Quality Processes	71	8,976,917	9,299,899	18,276,816
Biology	30	3,307,211	3,398,882	6,706,093
Economics and Management	33	3,282,564	3,571,429	6,853,993
Climate and Hydrology	49	5,323,454	5,402,565	10,726,019
Totals	260	29,852,134	30,985,254	60,837,388

Awards

Interest Area	No.	Federal ($) Funds	Non-Federal Funds($)	Total Funds($)
Ground-Water Flow and Transport	6	709,087	711,105	1,420,192
Treatment Processes	4	533,503	541,117	1,074,620
Water-Quality Processes	5	705,585	729,135	1,434,720
Biology	5	501,350	514,155	1,015,505
Economics and Management	9	1,022,434	1,073,132	2,095,566
Climate and Hydrology	7	909,041	923,728	1,832,769
Totals	36	4,381,000	4,492,372	8,873,372

Table 2.--Proposals and awards by organization, fiscal year 1989

Proposals

Organization	No.	Federal($)	Non-Federal Funds($)	Total Funds($)
Academic Institutions	245	28,526,106	29,458,391	57,984,497
Non-Federal Government	5	488,071	583,850	1,071,921
Private	10	837,957	943,013	1,780,970
Total	260	29,852,134	30,985,254	60,837,388

Awards

Organization	No.	Federal($)	Non-Federal Funds($)	Total Funds($)
Academic Institutions	34	4,213,416	4,324,788	8,538,204
Non-Federal Government	1	90,848	90,848	181,696
Private	1	76,736	76,736	153,472
Total	36	4,381,000	4,492,372	8,873,372

SECTION I

PROJECT SUMMARIES

FISCAL YEAR 1989 GRANTS

GROUND-WATER FLOW AND TRANSPORT

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1720

PROJECT TITLE: Measurement of Macropore-Scale Processes in Organic Contaminant Transport Using Computed Tomography

PERFORMING ORGANIZATION: University of Missouri

PRINCIPAL INVESTIGATOR: Stephen H. Anderson and Lee Peyton

DURATION: September 1989 to August 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Structured, heterogeneous porous media present serious problems to environmental scientists and engineers in understanding and predicting the important influence of small-scale structural variations on water and contaminant movement in ground-water environments. Among the most difficult variables to estimate in vadose zone transport are the pore-water velocity, dispersivity and the retardation factor. The difficulty relates to the complexity of in-situ measurements and the spatial variability of the values. This project proposes to investigate this variability on a macropore scale using X-ray computed tomography, a state-of-the-art technology in medical science. This project will use X-ray computed tomography to produce rapid, nondestructive, three-dimensional, small-scale (1 mm x 1mm x 2mm) measurements of natural soil structural features and measurements of water and organic solute movement through these soils.

2. Contribution to Problem Solution.

This project will develop methods and techniques for the applications of computed tomography to ground-water quality research. It will produce three-dimensional measurements of water and organic solute movement through soil that can be used to test and verify the increasingly sophisticated deterministic theories of flow and solute transport through heterogeneous porous media. It will improve estimates of small-scale spatial variability used in stochastic modeling of field-scale transport. The methods and techniques developed will indicate how computed tomography can be used to study important processes, such as dispersion, sorption, and characteristics of immiscible organic compounds.

3. Objectives.

The objectives of this research are to:

(a) Investigate the suitability of organic contaminants as tracers in X-ray computed tomography studies in soil;

(b) Determine the frequency distributions for pore-water velocity, dispersivity and the retardation factor on a macropore scale for two soils using selected organic contaminants and a tracer; and

(c) Evaluate the influence of a range of sample volumes for estimating the distributions of transport parameters.

4. Approach.

Selected organic contaminants containing elements with high atomic numbers will be evaluated for potential use as solute tracers with X-ray computed tomography. Soil-column breakthrough experiments will be conducted using a selected organic contaminant introduced in uniformly-packed and undisturbed soil. The soil columns will be scanned at selected locations along the soil columns throughout the experiments. By use of the data from the scans, the pore-water velocity, dispersivity, and retardation factor will be estimated on a macropore scale.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1726

PROJECT TITLE: Application of High-Resolution Subsurface Imaging Techniques to Water-Resource Investigations

PERFORMING ORGANIZATION: University of Arizona

PRINCIPAL INVESTIGATOR: B. Sternberg and S. Davis

DURATION: July 1989 to December 1990

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Electrical geophysics methods have been used successfully in the past for ground-water investigations. Electrical resistivity measurements have been shown to be generally valuable for determining a number of subsurface properties that are important for water-resource studies, including: porosity, fracturing, depth to water table, depth to bedrock, water quality, and rock type.

A major limitation of previous electrical geophysics methods (DC resistivity and electromagnetic) is that the measurements consisted of relatively widely-spaced stations. It was commonly difficult to correlate measurements from control-well to control-well or even measurement-site to measurement-site. Consequently, the interpretations of the data were limited to generalized pictures of the subsurface resistivity structure. Use of a high-resolution electromagnetic imaging system will lead to improve data correlation.

2. Contribution to Problem Solution.

The research effort adapts a recently developed high-resolution electromagnetic (EM) imaging system to practical problems related to the evaluation of ground-water resources, particularly problems of water contamination. If high-resolution soundings can be achieved, it will greatly improve the ability to monitor and characterize the condition of the subsurface environment.

3. Objectives.

To develop high resolution electromagnetic procedures to image water resources and contamination.

4. Approach.

The research will consist of four phases: (a) identification of suitable test sites; (b) acquistion of field data using the Laboratory for Advanced Subsurface Imaging (LASI) high-resolution Electromagnetic (EM) sounding system; (c) adaptation of image processing algorithms to the water-resource problem; (d) evaluation of the capabilities of this system for water-resource studies.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1738

PROJECT TITLE: Estimating Space and Time Variability of Nonpoint-Source Ground-Water Contamination

PERFORMING ORGANIZATION: Utah State University

PRINCIPAL INVESTIGATOR: U. Lall

DURATION: September 1989 to August 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem-Solution Approach.

Potential nonpoint-sources of pollution, such as irrigation, septic tanks, leaking gasoline reservoirs, leakage from waste storage sites can cause widespread contamination of ground-water quality. Extensive ground-water quality quality sampling activites are being conducted across the country to identify the degree of nonpoint-source contamination of ground water. An important aspect of ground-water monitoring (for regulation or for mitigation efforts) is the development of the means to infer accurately the extent and the movement of contaminants over both space and time from the data collected. The use of nonparametric regression techniques to simultaneously quantify the variability in contaminant concentration over space and time will lead to a general foundation for the analysis of contaminated field sites.

2. Contribution to Problem Solution.

The nonparametric and semiparametric regression techniques to be developed will allow the use of observations of contaminant concentrations to (a) characterize the variability of contaminant concentration across the site, and to (b) describe the change in concentration across the site over time. Techniques will be developed for estimating the concentration at points intermediate to the sampling locations at any specified time, for the identification of long-term trends, cyclical or seasonal variations of contaminant concentration, and to make short-term forecasts of likely contaminant concentrations across the site.

3. Objectives.

The general objective of this study is to develop robust nonparametric and semiparametric regression techniques that efficiently address the above issues. The specific objectives are to:

(a) take data on contaminant concentrations, water levels, and pumping volumes that have been collected at unequally spaced locations and at nonconcurrent times, and to estimate contaminant concentrations and mass at intermediate points in space and time; and

(b) develop an estimating technique that can relate the concentration not only to the location and the time, but also to water levels and pumping volumes.

4. Approach.

Heterogeneity and anisotropy of the aquifer media, as well as variability in the introduction of the contaminant to the aquifer (for example, through variations in irrigation practice) can lead to a high degree of variability and complexity in the pattern of contamination. The ground-water contamination pattern due to nonpoint-source pollution is usually nonstationary (the mean and variance of contaminant concentration are not constant) in both space and time. The statistical estimate of the plume from observations commonly is viewed as follows: The 'trend' or central tendency of the contaminant concentration in space and(or) time is estimated. Local deviations (or variability) from the trend caused by the effect of local heterogeneity on contaminant transport also are observed. Variability or 'noise' in the observed concentration values also may be present as a result of random fluctuations, sampling errors, and micro-regionalizations. The approach contemplated to solve the problem is the use of Generalized Cross Validated Thin Plate Smoothing Splines (GCV-TPSS). Splines are piecewise continuous polynomials that are typically fitted to a discrete data set. Smoothing splines allow the consideration of noise, local variability and nonstationarity in the data. GCV-TPSS are a recent extension of smoothing splines, and have convergence, consistency and robustness properties that are superior to parametric techniques, such as Kriging, for the problem outlined above.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1744

PROJECT TITLE: Field Experiments and Theoretical Analysis of Multi-Dimensional Pumped-Well Tracer Tests

PERFORMING ORGANIZATION: New Mexico Institute of Mining and Technology

PRINCIPAL INVESTIGATOR: C. Chen and D. Stephens

DURATION: June 1989 to May 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Hydrodynamic dispersion is an important process that affects contaminant movement in ground water. Field pumped-well tracer tests offered a practical means to quantify dispersion. There is evidence that suggests that dispersivities may increase with solute travel distance (that is, the scale-dependence problem). However, all previous pumped-well tracer tests did not take into account the transverse angular dispersion. We believe that neglect of the angular dispersion can lead to faulty results in calculated dispersivities. In this project, pumped-well tracer tests that take into account radial, angular and vertical dispersion will be conducted. Field data will be analyzed with a new multidimensional radial dispersion analytical solution corresponding to the test conditions.

2. Contribution to Problem Solution.

The research will contribute to our understanding of solute transport in ground water by:

(a) providing more detailed and complete methods for conducting and analyzing pumped-well tracer tests;

(b) acquiring field data that can be used to validate pertinent three-dimensional transport numerical models;

(c) enhancing our understanding of the scale-dependence problem;

(d) improving our understanding of the anisotropic dispersivity nature under radial-flow conditions; and

(e) producing state-of-the-art multidimensional radial dispersion theories using a deterministic approach; there is no equivalent radial dispersion stochastic approach, and, thus, this research will be useful to interested stochastic modelers.

3. Objectives.

The objectives of this research are to:

(a) assess the validity of the scale-dependence conditions of dispersivities; and

(b) improve pumped-well tracer test techniques by incorporating the concerns of angular dispersion, aquifer horizontal anisotropy, and the tracer-injection method.

4. Approach.

The objectives will be accomplished by conducting well-designed pumped-well tracer tests at a field site in New Mexico. The data will be analyzed with appropriate analytical solutions developed for this project. Both the field experiments and associated data analysis will take into account the angular variation and aquifer anisotropy. The tracer injection will be improved by using the proposed "sectional emitter," which minimizes the uncertainties caused by the "well-mixed" assumption inside the injection well. All the three concerns (angular variation, aquifer anisotropy, sectional tracer injection) have not been included in previous pumped-well tracer tests, and they will lead to improved field data for evaluating the scale-dependence problems as well as other related transport problems.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1747

PROJECT TITLE: Percolation Network Models to Predict Constitutive Relations for Multiphase Flow in Porous Media

PERFORMING ORGANIZATION: Princeton University

PRINCIPAL INVESTIGATOR: M. Celia

DURATION: September 1989 to September 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Hydrocarbon contaminants from leaky tanks and industrial waste sites commonly enter the subsurface as a separate nonaqueous phase liquid (NAPL). These relatively immiscible compounds may remain in the subsurface for many years, functioning as a source of contaminants to ground water. Meaningful analysis of the multiphase system is currently limited by a lack of information about specific material properties. This is especially true for the unsaturated zone, wherein three fluid phases, two liquid and one gas, can coexist.

2. Contribution to Problem Solution.

The research effort will help to clarify the fundamental fluid characteristics of the three-phase systems and contribute to the development of physically meaningful three-phase predictive models.

3. Objectives.

The objectives of this research are to:

(a) develop a complete theory of three-phase quasi-static displacement in porous media;

(b) extend the three-dimensional model to predict the relative permeability-saturation relation; and

(c) validate the relative permeability model by comparison to two- and three-fluid experimental data.

4. Approach.

A complete theory of three-phase quasi-static displacement in porous media will be developed by an interactive program of theoretical analysis and specific laboratory experiments. The experiments will provide insight into fundamental pore-scale characteristics of three-fluid porous media systems, which remains poorly understood. Results from these experiments will guide

the development of three-phase predictive network models for the capillary pressure-saturation relation. Both the computational and laboratory models will be used to examine several practical questions critical to modeling three-phase contaminant transport.

The three-dimensional percolation-based model of quasi-static immiscible displacement will be extended to include the dynamic case of creeping flow, from which the relative permeability-saturation relation will be derived. This will provide us with a complete constitutive model for capillary-dominated porous media characteristics. The model will be used to predict capillary pressure-saturation and relative permeability-saturation relations for two- and three-fluid systems.

The relative permeability model will be validated by comparison to existing laboratory data. Two two-fluid cases will be considered--an unsaturated soil (soil-air-water) and a NAPL-contaminated soil (soil-water-NAPL). The three-fluid algorithm will be tested with data reported in the petroleum literature (rock-water-oil-gas).

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1749
PROJECT TITLE:	Preferential Flow in Sandy Soils Overlaying Aquifers: Theory, Application, and Monitoring
PERFORMING ORGANIZATION:	Cornell University
PRINCIPAL INVESTIGATOR:	T. Steenhuis and J. Parlange
DURATION:	June 1989 to May 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Large quantities of nitrogen and more than 400 different types of pesticides are applied every year to America's cropland. Nitrogen and pesticides at certain concentrations in ground water that is used for drinking purposes can be a problem because they can cause birth defects, cancer, and other health problems. Many of these problems are of increasing concern because even trace quantities of these substances in water can have a long-term chronic effect on human. The multitude of chemicals used in a variety of combinations also can have a negative synergistic effect on humans. This combined with the long clean-up time associated with remediation of contaminated ground water emphasizes the need to prevent or minimize chemical contamination of ground water.

2. Contribution to Problem Solution.

The research effort will improve the understanding of chemical transport and lead to improved sampling strategies for contaminants in the unsaturated zone in the coarse-textured soils found above major aquifers in the States along the Atlantic Coast.

3. Objectives.

The objectives of this research are to:

(a) examine and develop the theory for preferential flow in homogeneous prewetted coarse-textured soils;

(b) adapt existing theories to include factors such as the influence of small root hairs and the effects of fine/coarse particle interfaces of soils having different hydraulic properties; and

(c) develop and test monitoring sampling networks that will provide early warnings of ground-water contamination and that will function even though preferential flow exists.

4. Approach.

The laboratory experiments will use specially designed two- and three-dimensional chambers, filling and packing apparatus and a unique light-video technique for monitoring changes in soil-moisture contents. Chemical solutions will be applied on soils at low rates to induce unsaturated flow. The number of preferential flow paths detected, their cross-sectional area, average moisture content, spacing and velocity, as well as the flow and solute flux through individual flow paths will be measured. By use of light-video techniques, the exchange of solute between the core and fringe areas of the flow paths will be determined. Dimensional analysis will assist in developing the models to predict preferential solute transport through these soils. The field experiment will verify the laboratory developed formulations and assist in designing sampling networks that function in the presence of preferential flow.

TREATMENT PROCESSES

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1721

PROJECT TITLE: Treatment of Membrane Surfaces with Oriented Monolayers for Improved Renovation of Impaired Waters

PERFORMING ORGANIZATION: Eastman Kodak Company

PRINCIPAL INVESTIGATOR: L. Speaker

DURATION: August 1989 to July 1990

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Industrial processing can contaminate large amounts of water by the contribution of their by-products and wastes. Typical contaminates are heavy metals from the metal finishing and electroplating industries. Membrane processing, a preferred route to cleanup, is complicated by the presence of diverse organic, inorganic, collodial and oily materials that adsorb on membrane surfaces. This fouling severely compromises membrane performance and raises the dollar and energy costs of effluent renovation.

2. Contribution to Problem Solution.

Determining the effectiveness of anti-fouling technology's (AFT) for preventing membrane fouling by oils, collodial silicates, and iron hydroxides and maintaining membrane permeabilities, selectivities, and rejection characteristics will contribute to improved understanding of the causes, mechanisms, and prevention of membrane fouling.

3. Objectives.

The objectives of this research are to:

(a) test our hypothesis that AFT will be effective against foulants other than humates;

(b) determine whether the low-wettability fluorinated surface of an AFT-treated membrane is critical in preventing fouling;

(c) examine the effects of step-wise modification of the molecular characteristics of potential AFT compounds on wettabilities and fouling propensities;

(d) compare the selectivities of AFT-treated membranes for pollutant metal ions against those of untreated membranes;

(e) enhance the understanding of membrane fouling and fouling in general; and

(f) contribute to the development of effective strategies for removal of water hardeners from natural sources and heavy-metal pollutants from industrial effluents.

4. Approach.

Commercially available reverse osmosis membranes will be coated with monolayers prepared from a variety of precursors. Those materials that cannot be purchased will be synthesized. Each monolayer coating on the membrane substrates will be evaluated by state-of-the-art spectroscopic techniques, and by contact angle measurements for several test liquids. Coated membranes will be tested in a high pressure, stirred, reverse osmosis cell. Each membrane treatment will be evaluated for its effectiveness in mitigating fouling by several important and representative fouling materials. Each treatment also will be evaluated for its effect on permeate flux and ion-rejection rate for salts of several divalent metal ions. Data will be analyzed in order to correlate important variables, including monolayer structure, coated membrane wettability, foulant, metal salt, permeability, and rejection levels. The literature will be studied for pertinent background data, and compared with the new results obtained.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1727

PROJECT TITLE: Enzymatic Detoxification of Phenols and Pesticide Residues in the Aquatic Environment

PERFORMING ORGANIZATION: Pennsylvania State University

PRINCIPAL INVESTIGATOR: J. Bollag

DURATION: September 1989 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

The presence of aromatic phenolic compounds and pesticide residues in industrial waste effluents and ground and river water has caused great concern because these chemicals create serious public health and water-quality problems. Furthermore, large discharge of these industrial aqueous effluents annually into United States coastal water may result in adverse consequences for the biosphere. To avoid such effects, it is necessary to reduce potential sources of chemical pollution and to develop strategies and techniques for solving pollution problems in-situ.

2. Contribution to Problem Solution.

Biotechnological procedures, for example production and/or application of microbial enzymes in situ, may constitute an approach for controlling pollution.

3. Objective.

The objective is to destroy, or at least reduce, the toxicity of phenolic compounds, pesticides, or other xenobiotics, in aquatic environments. This research effort will further this aim by contributing to the development of bioreactors containing immobilized enzymes that would efficiently remove toxic phenols and pesticide residues from aquatic environments.

4. Approach.

This research will use two types of immobilized enzymes, oxidoreductases and hydrolases, for removing or detoxifying phenolic and pesticidal compounds from and in waste and ground water. The approach is based on the observation that oxidoreductases oxidize phenols and other aromatic compounds into water-insoluble polymers which then can be removed from the aquatic environment by sedimentation or filtration. This method could prove to be a valuable means for controlling pollution in ground water and wastewater. Hydrolases are also capable of transforming numerous pesticides and other xenobiotics. Products of hydrolyzed substances are frequently phenols and aromatic amines, and these chemicals can be further oxidized by specific oxidoreductases. Thus, co-immobilization of the two types of enzymes should result in a broad-spectrum system for the removal of a variety of xenobiotics. In addition, xenobiotics can be bound to humic substances through the activity of

oxidoreductive enzymes. By using immobilized oxidoreductases to initiate the binding of xenobiotics to soil particles, it is expected to be able to influence their uptake by organisms, to reduce their toxicity, and to avoid their leaching into ground water.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1733

PROJECT TITLE: Biodegradation of Organopollutants by a White Rot Fungus in Bench Scale Reactors

PERFORMING ORGANIZATION: Utah State University

PRINCIPAL INVESTIGATOR: J. Bumpus, R. Sims, and D. Stevens

DURATION: September 1989 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Currently available technology for biological treatment of wastewater is sometimes insufficient to decontaminate wastewater containing certain hazardous, environmentally persistent chemicals such as polyaromatic hydrocarbons (PAHs), pentachlorophenol and N, N, N', N', N"-hexamethylpararosaniline (crystal violet). It is planned to study the kinetics of biodegradation of these organopollutants by the white rot fungus Phanerochaete chrysosporium in a bench-scale mechanically mixed suspended growth batch flow reactor and develop a practical fluidized bed reactor, using this fungi, that is suitable for scaleup.

2. Contribution to Problem Solution.

The research should result in the development of a wastewater treatment system designed to treat waters contaminated with environmentally persistent chemicals.

3. Objectives.

The major objectives of the research are to study the kinetics of xenobiotic biodegradation by P. chrysosporium and to develop a practical wastewater treatment system to degrade environmentally persistent chemicals in such water. Other objectives are to determine:

(a) the optimum conditions which promote biodegradation;

(b) if toxic or recalcitrant intermediates are made; and

(c) if biodegradation can be accelerated by adding supplemental biodegradative enzymes (ligninases) to these biodegradation systems.

4. Approach.

Biodegradation of two representative PAHs (Benzo[a]pyrene and phenanthrene), p-cresol, pentachlorophenol and crystal violet will be studied in bench scale reactors. Biodegradation will be monitored by disappearance as well as mineralization (degradation to CO_2) of ^{14}C-labeled benzo[a]pyrene, p-cresol, phenanthrene, pentachlorophenol and crystal violet. Metabolite formation also will be monitored as will disappearance due to volatilization.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1739

PROJECT TITLE: Removal of Contaminants from the Vadose Zone by Pneumatic Fracturing

PERFORMING ORGANIZATION: New Jersey Institute of Technology

PRINCIPAL INVESTIGATOR: J. Schuring and P. Chan

DURATION: July 1989 to June 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

The water-related problem targeted for study is water-quality management of natural water systems. The research will specifically focus on development of an improved method for in-situ treatment and control of hazardous contaminants in the vadose soil zone. The proposed new method, known as "pneumatic fracturing," consists of injecting high pressure air into the contaminated soil formation to create a secondary network of fissures and channels in the soil matrix. This increases the permeability of the soil to liquids and vapors which will accelerate virtually any method of removal and/or treatment. It is anticipated that pneumatic fracturing can be used to enhance a number of cleanup methods including vapor extraction, biodegradation and thermal treatment. Pneumatic fracturing is a potentially transportable technology.

2. Contribution to Problem Solution.

The research will contribute an improved method for in-situ treatment of contamination in the vadose soil zone. The study will also provide a better scientific understanding of the fracture mechanics of geomaterials and unsaturated transport in fractured media. Prompt treatment of the vadose zone is important in any ground-water remediation actions since studies have shown that it is more effective and less costly to remove VOC's from the vadose zone than from the saturated zone.

3. Objectives.

The objectives of this project are to:

(a) demonstrate that pneumatic fracturing is technically feasible and can enhance the efficiency of various in-situ remediation methods for the vadose zone;

(b) develop a theoretical basis for the pneumatic fracturing process including the fracture behavior of soil and the unsaturated transport of contaminants through a fractured soil medium; and

(c) develop and test a prototype pneumatic fracturing system in the field, and gather information on the operation, cost, and effectiveness of the process.

4. Approach.

The initial phase of the project will focus on bench scale experiments and formulation of a theoretical soil fracture model. Using this information and previously collected laboratory data, a prototype device will be developed. The prototype device will be evaluated at a noncontaminated site to investigate the soil fracture behavior, contaminant transport characteristics, removal efficiency, layout geometry, and operation factors. The field demonstration will utilize in-situ instrumentation and control data to evaluate the effectiveness of the system. The sites will be selected in New Jersey by the researchers and New Jersey Department of Environmental Protection in concurrence with the U.S. Geological Survey.

WATER-QUALITY PROCESSES

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1722

PROJECT TITLE: Extension of U.S. Environmental Protection Agency (USEPA) Method 531 for the Analysis of Nitrogenous and Aromatic Pesticides in Ground Water

PERFORMING ORGANIZATION: University of Florida

PRINCIPAL INVESTIGATOR: H. Moye

DURATION: June 1989 to May 1990

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Many pesticides that enter the ground water cannot be quantitated in a sensitive, selective and reliable manner due to the unavailability of adequate analytical methods. Of the 360 pesticidal active ingredients currently registered in the United States, less than half of them can be studied for their presence, degradation rates, and movement patterns in ground water until such analytical methods are developed.

2. Contribution to Problem Solution.

The availability of improved analytical methods will reduce cost and increase the number of the different pesticides that can be monitored. It will also provide easier and cost effective methods to use for soil physicists, hydrogeologists, and environmental scientists. Being able to effectively study such behavior will ultimately lead to a better understanding of the nature and fate of pesticides in the subsurface environment and thereby protect ground-water quality.

3. Objective.

The primary objective of this research is to expand the number of pesticides that can be analyzed in ground water at trace levels by extending the USEPA Method 531 that now covers N-methylcarbamate and carbamoyl oxime pesticides.

Secondary objectives will be to:

(a) maximize detector sensitivity by selection of photolysis lamp type, photolytic solvent, and type of photosensitizer when needed;

(b) maximize chromatographic resolutions and peak capacity by proper choice of analytical columns and elution solvent programs; and

(c) maximize method limits of detection by selection of optimum solid phase extraction (SPE) cartridges when limits of detection (LOD) less than 1 mg/L cannot be achieved by direct water injections.

4. Approach.

Forty pesticides found from previous studies at this laboratory to form intense fluorophores, either directly upon photolysis or upon photolysis followed by reaction with the o-phthalaldehyde reagent, will be reexamined using the zinc photolysis lamp, which emits at more energetic wavelengths than does the previously studied mercury lamp (218 nm versus 254 nm). For those pesticides that show a significant amount of fluorescence directly upon photolysis without addition of the o-phthalaldehyde reagent, fractions will be collected from the photoreactor and fluorescent excitation and emission spectra taken with a recording spectrophotofluorometer. The information thus gained will be used to program the wavelength programmable high performance liquid chromatographic (HPLC) fluorescence detector during method development. An additional 10 pesticides of aromatic character will be studied for their photolysis efficiencies using both the mercury lamp and the zinc lamp.

Reverse phase chromatographic separations will be developed using solvent programming so that complete resolution of each pesticide from adjacent eluters will be obtained at retention times of no more than 20 minutes. Pesticides will be grouped into one of four groups, according to whether they produce maximum fluorescence under mercury or zinc lamp irradiation and whether they produce maximum fluorescence in water:methanol or in water:acetonitrile.

For those pesticides that cannot be injected on the reverse phase anlytical HPLC columns at volumes of 0.4 mL or greater without causing band broadening of more than 10 percent, a study will be conducted to identify SPE cartridges for removing the pesticides from larger volumes of water, thereby extending the LOD.

Depending upon how the 40 to 50 pesticides can be grouped, according to what mobile phase solvents are required for their separation, there will be probably two or more methods developed which may also differ by whether SPEs are required or not to achieve maximum LODs. These methods will be validated by determining percent recoveries for various fortification levels, by determining limits of detection, by determining standard deviations for replicate analyses, and by determining storage stability times for typical ground-water samples held under refrigeration for various intervals of time.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1728

PROJECT TITLE: Extensions of Random Walk Modeling for Pollutant Transport

PERFORMING ORGANIZATION: University of Texas

PRINCIPAL INVESTIGATOR: E. Holley

DURATION: September 1989 to August 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Pollutant transport modeling typically involves two stages: determination of the hydrodynamics (depths, velocities, etc.) and then use of this information as input for the pollutant transport modeling. This research is concerned with the transport phase of the modeling. Traditional finite difference and finite element models do not allow modeling of pollutant clouds smaller than the grid sizes in the models (typically 1 to 2 km for bay models). Thus, they have little utility for the initial part of problems such as accidental spills or discharges, and it is during the initial phases that the maximum concentrations exist. Also, these models have severe numerical spreading of the pollutant cloud when it is as large as even 10 grid sizes. This numerical spreading results in predicted maximum concentrations being too low and in the predicted size of the cloud being too large.

2. Contribution to Problem Solution.

Random walk models (RWMs) offer an alternative to overcome many of the problems with traditional methods. In RWMs, the pollutant cloud is represented by discrete particles which undergo advective displacements to represent the movement due to the velocity and random dispersive displacements to represent the mixing.

Thus, the transport is simulated by the particles, as contrasted to being studied by solving the governing equations. RWMs can represent point source initial conditions (for example a drum of toxic materials falling off a dock), and they have no numerically generated spreading (numerical dispersion) of the pollutant cloud. The development and application of these models has been primarily (but not totally) for conservative pollutants; the techniques which are presently used for non-conservative substances are inherently computationally inefficient. This research addresses this problem for the case of surface transfer of dissolved gases and volatile pollutants. It also addresses the handling of boundary conditions. Recent applications have revealed some possible problems in the ways that the random displacements are handled for changing depths and widths. The third aspect of the research is related to new problems which arise in association with the capability of simulating point sources, namely the question of how to model the transport of a cloud which is smaller than the grid size of available hydrodynamic information.

3. Objectives.

The objectives of this research are to develop and test improved techniques for representing:

(a) particle reflection at the boundaries;

(b) surface transfer of dissolved gases and volatile pollutants; and

(c) subgrid scale dispersion phenomena and the transition from subgrid dispersion for small pollutant clouds to cloud speading due to velocity differences at the grid points.

4. Approach.

For the boundary conditions, numerical results will be compared with analytical solutions for a wedge-shaped region from a radially symmetric diffusion problem; this will provide changing depths and widths. For the surface transfer, four different techniques will be tested for accuracy and efficiency. For the subgrid scale processes, a transition function will be developed to describe the required decreasing rate of increase of the dispersion coefficient as the cloud size increases; more and more of the spreading in the model is then coming from the differential advection at the hydrodynamic grid point within the cloud rather than from the dispersion coefficient.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1734

PROJECT TITLE: Inorganic Nitrogen and Phosphorous Dynamics in the Water Column of the Patuxent River

PERFORMING ORGANIZATION: University of Maryland

PRINCIPAL INVESTIGATOR: D. Capone, G. Muller-Parker, and L. Duguay

DURATION: July 1989 to June 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Phosphorus (P) has been found to be the nutrient limiting algal growth in many riverine systems and has therefore been the object of control strategies. The Patuxent River is noteworthy in that the limiting nutrient seems to vary seasonally and, over all, nitrogen (N) appears to be the most important nutrient contributing to eutrophication. This observation, which is based on experimental mesocosm studies and direct observations of seasonal trends in nutrient concentration, has prompted a State-supported effort to reduce point source nutrient loading in the river with particular focus on N. A knowledge of rates of inorganic N and P uptake and turnover with respect to nutrient pools and cellular requirements is essential to understanding nutrient dynamics and the seasonal shift in the nature of limiting nutrients. While numerous studies of other systems have considered either N or P uptake by phytoplankton, there is little information on concurrent rates of N and P uptake in individual systems, and virtually no information in systems which apparently vary between N and P limitation annually, or which have been subject to nutrient abatement. Our knowledge of the responses of nutrient dynamics to interannual variations in river flow is also rudimentary.

2. Contribution to Problem Solution.

The Patuxent can be a model "experimental" system within which to study the relationships of plankton populations with seasonally varying nutrient limitation and the effect of nutrient abatement on nutrient dynamics. An ongoing State supported monitoring program provides a solid framework for process-oriented studies. With the advent of nutrient reductions to the river, our research will provide an essential base-line from which we can more fully understand the effect of nutrient abatement on the ecosystem.

3. Objectives.

In order to understand the interaction of the nutrient field with the dynamics of nutrient uptake and limitation, as well as to possibly discern the more subtle effects of nutrient abatement, we propose to undertake a detailed investigation of N and P uptake and regeneration in the water column of the Patuxent. We specifically propose to assess planktonic PO_4^{-3}, NO_3^- and NH_4^+ uptake and water-column NH_4^+ and PO_4^{-3} regeneration on a seasonal basis at three stations on the river ranging from freshwater to estuarine conditions.

4. Approach.

Planktonic nutrient limitation is directly evaluated by defining the rate of uptake of N and P, with respect to availability and cellular requirements. We will therefore assess planktonic PO_4^{-3}, NO_3^- and NH_4^+ uptake and water-column NH_4^+ and PO_4^{-3} regeneration on a temporal basis at stations along the salinity gradient of the river. We will also evaluate the specific contributions of picoplankton and heterotrophic bacterioplankton to nutrient uptake and regeneration. Evaluation of these processes over appropriate time scales and in conjuction with ongoing State monitoring of inorganic nutrients and phytoplankton populations will allow for a more detailed understanding of the relationship between loading and resultant concentrations of nutrients in the river, as well as the annual shift in limiting nutrient. The data collected will be used, in conjunction with other available data on river flow, input, productivity and benthic metabolism, to generate box models of N and P dynamics in the river.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1740

PROJECT TITLE: Movement and Dissipation of Toxicants and Water in Natural Soil Environments

PERFORMING ORGANIZATION: North Carolina State University

PRINCIPAL INVESTIGATOR: J. Weber and C. Miller

DURATION: June 1989 to May 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

The major limition in predicting ground-water contamination is the lack of understanding of the interactions among the processes involved in the dissipation of organic solutes in soil under natural conditions. Pesticides are an important source of such potential contaminants. Pesticide behavior in soil is effected typically by the processes of advection, hydrodynamic dispersion, evapotranspiration, volatilization, sorption/desorption, and degradation. While much work has been done in the area of pesticide process reactions, few studies have examined all of the operative processes for a given system. Only through such comprehensive approaches will realistic interpretations of process interaction and relative importance be determined.

2. Contribution to Problem Solution.

This research will add new information about the interaction of processes that affect the fate and transport of common organic solutes in the unsaturated soil zone. The expected results will also include new information about the feasibility of using polymers to limit the mobility of potential ground-water contaminants.

3. Objective.

The overall objective is to gain a better understanding of the interactions among the processes mentioned above for a range of typical pesticide-soil systems. This better understanding will include knowledge of the relative importance of each process as a function of pesticide type, soil, and climatic conditions. A further objective is to determine the extent that pesticide transport and transformation may be manipulated--through the use of polymer additives--to minimize contaminant mobility and maximize product benefits.

4. Approach.

The approach includes three key components: Controlled field studies, laboratory process studies, and mathematical modeling of field and laboratory studies. Controlled field studies will utilize 58 minilysimeters to evaluate the movement of water and three pesticides as a function of time, compound type, fertilizer content (nitrate), crop conditions, and polymer additive. A slug source of pesticide will be applied in radiolabled form, with lysimeter leachate collected continuously and analyzed weekly. Lysimeters will be sacrificed at discrete times, sectioned, and analyzed for tritiated water and pesticide distribution in the sorbed and fluid phase as a function of position. Parallel laboratory studies will be performed to determine a comprehensive range of physical and chemical characteristics of the field site materials as a function of position. Process studies will also be performed in the laboratory to determine the rate and products of biodegradation for each of the pesticides, and the sorption-desorption equilibrium and rate characteristics of each pesticide as a function of position. Experimental results will be interpreted using developed models, while a common model will be used to compare predicted conditions with observed conditions in the field.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1745

PROJECT TITLE: Development of Advanced Solvent Extraction Concentration Methods for Determining Trace Organic Compounds

PERFORMING ORGANIZATION: Oregon Graduate Center

PRINCIPAL INVESTIGATOR: J. Pankow and L. Isabelle

DURATION: July 1989 to July 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Many analytical methods could be improved if better ways could be found to concentrate solvent extracts. This is because many organic analytical methods employ some type of solvent extraction step. These methods include: (a) batch extraction; (b) continuous liquid/liquid extraction; (c) solid phase sorption followed by solvent recovery of the analytes; and (d) soxhlet extraction of soil or sediment samples. When studying low levels of contamination, solvent extracts must be concentrated prior to analysis. Kuderna-Danish (K-D) concentration and inert gas blowdown are often used to concentrate extracts. Unfortunately, K-D concentration is cumbersome and nitrogen blowdown often causes large losses. Solvent removal/thermal desorption (SRTD) and solvent removal/supercritical desorption (SRS) are two methods which have the potential to solve virtually all extract concentration problems. With SRTD, a large aliquot (e.g., 100 mL) of extract is loaded on a pre-column. Inert gas removes the solvent. The analytes are then thermally desorbed to a gas chromatography (GC) column for analysis. With SRSD, the analytes are transferred to the column using a supercritical fluid (e.g., CO_2). With SRSD, one may use GC, liquid chromatography (LC), or supercritical fluid chromatography (SFC). Because supercritical fluids operate well at ambient temperatures, SRSD with LC or SFC will likely be successful with organic compounds that are not thermally stable and therefore are currently difficult to determine.

2. Contribution to Problem Solution

This research will therefore fully develop and optimize SRTD and SRSD for use as high efficiency solvent extract concentration methods for the introduction of low level samples into gas, liquid, and super critical fluid chromatography (GC, LC & SFC). The high concentration powers of both SRTD and SRSD permit analyses of very small samples, for example very small suspended sediment samples.

3. Objectives.

The objectives of this research are to:

(a) select and obtain standard materials for a broad group of compounds of environmental interest;

(b) determine the thermal desorption conditions that will permit the optimal SRTD transfer of the selected model compounds to GC columns;

(c) investigate the effects of the identity of the solvent on the efficacy of SRTD and quality of the resulting gas chromatography;

(d) determine the supercritical fluid extraction conditions that will permit the optimal transfer of the selected model compounds by SRSF to GC, LC, and SFC columns;

(e) optimize the actual interfacing of SRSD to such columns; and

(f) apply SRTD and SRSD to extracts of complicated, real world samples.

4. Approach.

U.S. Environmental Protection Agency's (USEPA) disposal site monitoring list as well as its priority pollutant list will provide a list of model compounds. Standards will be obtained; custom syntheses will be used as needed. Experiments will determine the temperature, gas flow, and GC trapping temperatures that optimize SRTD transfers. Transfer efficiencies will be quantitated by GC/mass spectrometry. Sorption isotherms of all of the major SRTD solvents will be determined by gas/solid GC for the packing materials in SRTD precolumns (to permit optimal solvent removal). The SRSD transfer of analytes to chromatography columns will be optimized by varying: fluid identity, pressure, temperature, and the concentration of polarity modifiers. Analysis of variance (ANOVA) will be used to interpret the data. The model compounds will be segregated according to their being able to be determined by GC, LC, or SFC. The interfacing of SRSD with each of these types of chromatography will be optimized using the three compound groups. Three real world sites will be used to provide samples for the testing of SRTD and SRSD: (a) Pensacola creosote site (Florida); (b) Chem-Dyne USEPA Superfund site (Ohio); and (c) Alkali Lake (Oregon) pesticide manufacturing waste disposal site.

BIOLOGY

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1723

PROJECT TITLE: Evaluation of Mechanisms of Microbial Alteration and Humification of Polynuclear Aromatic Hydrocarbons for Water-Quality Management

PERFORMING ORGANIZATION: Utah State University

PRINCIPAL INVESTIGATOR: R. Sims

DURATION: September 1989 to August 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Polynuclear aromatic hydrocarbon (PAH) compounds are present in high concentrations in creosote wood preservative wastes that have contaminated ground waters and surface waters through contact with contaminated soils at over 1,100 sites in the United States. Understanding the microbial alteration and fate of biological transformation products of high molecular weight PAH compounds and the possibility of controlling transformation under cooxidation conditions where methane is present to stimulate aerobic methanotrophic cooxidation may provide a basis for the control of transformation for accomplishing destruction, detoxification, and removal of PAH compounds to protect supplies of potable water.

This research will investigate the fate of PAH transformation products, including water soluble species and mutagenic species, in unsaturated soil systems, as well as investigate the biological coupling of transformation products to humic materials. The use of methanotrophic cooxidation conditions for controlling the rate and extent of detoxification of high molecular weight PAH compounds in unsaturated soil samples also will be evaluated.

2. Contribution to Problem Solution.

Results of this research will provide information concerning the type of transformation products produced and the fate of those products in complex environmental systems. The potential for using a specific carbon source, methane, to stimulate naturally occurring methanothrophic microorganisms to accomplish biological destruction and detoxification of PAHs through specific biochemical mechanisms will be evaluated.

3. Objectives.

The objectives of this research are to:

(a) determine the distribution of transformation products of two radiolabeled PAH compounds, benzo[a]pyrene (B[a]P), and dibenz[a,h]anchracene (DB[a,h]A), among the phases of unsaturated soil, including solid, aqueous, and air phases;

(b) determine the extent of oxidative cross-coupling of transformation products of the two PAHs with soil humic material;

(c) determine the potential biohazard of solid and aqueous leachate phases using mutagenicity and toxicity assays; and

(d) determine the rate and extent of detoxification and destruction of transformation products in soil containing B[a]P and DB[a,h]A acclimated with a 5-percent to 95-percent mixture of methane:air and provided with methane during incubation.

4. Approach.

Laboratory microcosms will be used for evaluating single PAHs individually and PAHs present in creosote waste-contaminated and uncontaminated unsaturated soil zone samples collected from several sites in the United States, which will be provided by the U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma. Soils representing a range in soil characteristics will be used in laboratory partitioning, toxicity, and humification studies.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1729

PROJECT TITLE: Extraction of the Heavy-Metal Inducible Peptide, Phytochelatin, from Freshwater Plants as a Biomonitoring Method

PERFORMING ORGANIZATION: Portland State University

PRINCIPAL INVESTIGATOR: J. Rueter, Jr.

DURATION: June 1989 to May 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

It is difficult to monitor and assess the impact of low level and occasional inputs of heavy metals into freshwater ecosystems. Some plants have intracellular sequestration mechanisms that allow the plants to survive heavy-metal exposure but these mechanisms may also cause accumulation in the food chain.

2. Contribution to Problem Solution.

Studying detoxification and concentration mechanisms in freshwater plants may help us both estimate the exposures to heavy-metals and understand the fate of these metals in the ecosystem. There is an identical detoxification mechanism in all of these species, for example synthesis of phytochelatin, so the isolation and metal content of phytochelatin should be an excellent indicator of heavy metal exposure.

3. Objectives.

The objectives of this research are to:

(a) test the hypothesis that cadmium induces and binds to phytochelatin in plants from 10 species selected from aquatic habitats;

(b) select a feasible method for isolating the phytochelatin fraction and measuring the composition of bound heavy-metals; and

(c) use the selected isolation technique for phytochelatin in a direct comparison with current biomonitoring techniques.

4. Approach.

The approach is similar to the highly successful biomonitoring technique in marine systems using the common mussel, Mytilus edulis, as a bioaccumulator and examining the binding of heavy metals to its metallothionein fraction. This approach has been applied to monitoring pollution in estuaries, coastal outfalls and even a global monitoring program ("Mussel Watch"). Freshwater mussels and bivalves are rarer and smaller making them unsuitable for routine biomonitoring work. The newly characterized cadmium binding proteins from plants that are highly conserved between taxonomic groups may provide a biochemical fraction for biomonitoring similar to the metallothionein in mussels. Collecting aquatic plants is easier, and determining the site of exposure is more certain than the current practice of using fish for metals biomonitoring.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1735

PROJECT TITLE: Sources and Accumulation of Heavy Metals in Sediments and the Clam Corbicula Fluminea in Two South Carolina Watersheds

PERFORMING ORGANIZATION: South Carolina Department of Health and Environmental Control

PRINCIPAL INVESTIGATOR: J. Pickett

DURATION: August 1989 to March 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Population growth and associated urban, industrial and agricultural development have made significant contributions to the contamination of the Nation's river basins. Excessive amounts of trace metals and other potentially toxic substances enter aquatic ecosystems through point-source discharges and nonpoint-source runoff.

Given a heavy metal dose and water hardness, toxic effects to the aquatic biota can be elicited upon exposure. These effects can be as subtle as altered respiration or growth rates or as overt as a fish kill. Some metals such as iron, calcium and manganese, at intrinsically-appropriate levels, are considered essential elements for proper metabolic functioning of aquatic organisms. Other metals such as cadium, chromium, copper, lead, mercury and nickel are considered toxicants, as they can exert deleterious effects at very low concentrations. When introduced to receiving waters, metals are partitioned between the solid phase (sediments, food) and the liquid phase (water column). If contamination of a fluvial system exists, the evidence usually resides in the sediments or biota long after soluble fractions of the contaminants are flushed from the system. Also, the bioconcentration from water, bioaccumulation from ingestion of food and sediment and biomagnification through the food web of toxic heavy metals are important concerns.

Once introduced into an aquatic system, metals are preferentially partitioned to the sediment in direct relation to decreasing particle size and/or increasing organic matter content. Once in the sediments, metals will usually remain there until disturbed physically or chemically at which time the sediment sink becomes exposure source at levels much higher than the overlying water column. Of course, the benthic infaunal and epifaunal organisms are exposed to the sediment pool even as it functions as a sink.

2. Contribution to Problem Solution.

Biological organisms are exposed to and take up metals from both the solid and liquid phases. Because of extrinsic geophysicochemical factors governing sediment-metal chemistry and intrinsic physiological factors governing organismal uptake/retention, organisms are rarely, if ever, exposed to a metal as a single entity. Thus, the portion of a metal that is bioavailable becomes the critical focus for determining toxicity risk to the biota and true contamination status of a watershed.

3. Objective.

The primary objective of this study is to determine the bioavailability of heavy metals to the freshwater clam, Corbicula fluminea, from sediment and water column exposures as associated with surface-water runoff.

Specific objectives are as follows:

(a) determine total stream loadings of heavy metals to Lake Marion through the Congaree and Wateree Rivers;

(b) partition total stream loadings of heavy metals into point- and nonpoint-source components; and

(c) determine extent of heavy metal accumulation in Corbicula fluminea and sediments and the bioavailability of sediment-associated heavy metals to C. fluminea.

4. Approach.

The project will be accomplished through an intensive sampling of water column metals for all substantial runoff events during a 2-year period through the use of automated samples stations. Point-source dischargers within the subbasins of interest will be sampled and point-source contribution will be subtracted from total loadings to estimate nonpoint-source contribution. Monthly sediment and clam tissues analyses will provide data to determine accumulation in both media and bioavailability of sediment-associated heavy metals to clams.

This effort would be in conjunction with routine monitoring of the Santee-Cooper lake system conducted by the Public Service Authority, which consists of 30 in-lake stations sampled monthly. It also coincides with a descriptive assessment of water quality and hydrology of Lake Marion's headwaters, and, in addition, the data from this study could be incorporated into a geographical information system now being developed to define critical areas of nonpoint-source runoff. Together, the separate components would lead to an integrated analysis of lake conditions relative to loading and potential biological responses. Furthermore, the linkage with nonpoint-source compared to point-source loading presents the opportunity for realistic and effective environmental management using a well-defined data base as a guide for regulatory and resource decisionmaking.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1741

PROJECT TITLE: Gene Probe Detection of Pathogens in Sludge-Amended Soils

PERFORMING ORGANIZATION: University of Arizona

PRINCIPAL INVESTIGATOR: I. Pepper

DURATION: July 1989 to June 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Utilization of municipal sludges and effluents on agricultural, range and forest land is now a common and accepted practice in the United States. These materials frequently contain bacterial pathogens capable of surviving in soils for significant periods of time, and migrating to underground aquifers. The potential hazard of these organisms is a function of their ability to survive in soils relative to their mobility in soils. Traditionally, bacteria have been detected by use of selective enrichment and culture procedures. However, these techniques may not detect organisms that have been injured during treatment of sludge and/or effluent for example by chlorination. These injured organisms may be capable of surviving but may be non-culturable. Thus, traditional methods may underestimate the hazards of pathogens applied to soil via municipal wastes. Gene probes prepared from specific DNA sequences are a new attractive method of detecting specific organisms, but little data is currently available on their use in soils. We will evaluate the use of gene probes to detect viable bacterial pathogens in sludge-amended soils, including injured organisms which may be non-culturable. We also will increase the sensitivity of gene probes for environmental detection of pathogens by the use of polymerase chain reaction (PCR).

2. Contribution to Problem Solution.

The successful evaluation of highly sensitive specific gene probes for pathogens would allow survival and mobility studies to be more precise, and would aid in the risk assessment of pathogens added to soil and water via municipal waste.

3. Objectives.

The objectives of this research are to:

(a) determine the ability of gene probes to differentiate between viable and "injured" bacterial pathogens in soil;

(b) determine the sensitivity and specificity of gene probes to detect pathogenic organisms in sludge-amended soils;

(c) improve the sensitivity of gene probes by use of polymerase chain reaction; and

(d) compare gene probe technology with conventional enrichment and culture techniques for pathogenic detection in sludge-amended soils.

4. Approach.

Gene probes are currently available in our laboratories for specific bacterial pathogens. We will evaluate the sensitivity and specificity of these probes, first in sterile soils, and later in non-sterile soils. Soils amended with sludge, as well as genomic DNA, or viable pathogens, or "injured organisms" will all be probed and where appropriate, data compared to that obtained from conventional techniques. A new PCR technique will be attempted to improve the sensitivity of gene probes.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1816

PROJECT TITLE: E. Coli and Water Quality: Reevaluation of MUG Tests and Development of a Radical New Indole Test

PERFORMING ORGANIZATION: University of California, Berkeley

PRINCIPAL INVESTIGATOR: G. Chang

DURATION: September 1989 to September 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

There is an urgent need for a simple and specific test for E. coli, the bacterial indicator of fecal contamination in surface waters. Conventional tests are too slow and non-specific. Even the highly touted 4-methylumbelliferyl-B-D-glucuronide (MUG) test, part of the U.S. Environmental Protection Agency's Proposed Water Quality Standard, has a serious flaw. We discovered that the test fails to pick up a third of human fecal E. coli strains. The research will approach the problem of E. coli detection in three ways: a) get a clearer picture of the size of the problem. How widespread is the occurrence of MUG-negative E. coli? b) improve the MUG test. Can we use our MUG-negative strains to help us to modify the MUG test so that it will detect more E. coli? c) develop a radical new test for indole. Indole production is an old and well studied characteristic of E. coli.

2. Contribution to Problem Solution.

Improvement of the MUG test and development of a new indole test for E. coli will provide a faster better test procedure.

3. Objectives.

The objectives of this research are to:

(a) get a much wider picture of the failure rate of MUG tests in detecting fecal E. coli;

(b) modify MUG tests, enabling them to detect a larger percentage of fecal E. coli; and

(c) develop a radical new test for indole production, a well established and throughly studied characteristic of E. coli.

4. Approach.

In order to determine the magnitude of the problem of MUG-negative E. coli, fecal E. coli from additional human subjects and international culture collections will be examined. We will also collect and examine E. coli from ducks and other animals and from municipal wastewater at various stages of treatment and disposal. Several previous studies were misleading because they were based on clinical isolates of E. coli. In order to modify current MUG tests for E. coli, we will use our MUG-negative isolates as test strains and experiment with different media composition and test temperatures. Previous studies were based only on MUG-positive E. coli. In order to develop a radical new indole test, we will optimize a newly invented indole test. This confidential and proprietary invention consists of using a barrier membrane to separate the toxic test reagent from the growing bacterial culture. Indole diffuses through the membrane, but the reagent does not. Previous indole tests involve much more manipulation than the new invention. Most previous tests kill the cultures, making further bacteriological studies difficult.

ECONOMICS AND MANAGEMENT

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1724

PROJECT TITLE: An Economic Analysis of Low Input Agriculture as a Ground-Water Protection Strategy

PERFORMING ORGANIZATION: Virginia Polytechnic Institute and State University

PRINCIPAL INVESTIGATOR: S. Batie and D. Taylor

DURATION: September 1989 to September 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Agricultural pesticide contamination of ground water as a management issue contains all the complexities and uncertainties that were earlier associated with the ground-water problem in general, such as the toxicity and health effects of pesticides in ground water, costs of preventative and prescriptive activities, and the farmers concern of productivity. The farmer as a user of pesticides faces cancellation or suspension of some chemicals and fairly restrictive local and Federal Government regulations as to application of other chemicals. In the early 1980's, the use of several common chemicals, such as lindane and toxaphene, were cancelled and partial suspensions and special reviews of alachlor, aldicarb and 2, 4-D were enacted (U.S. Environmental Protection Agency (USEPA), 1985). Recently, Congress has had to address the legislative issues of ground-water contamination from agricultural pesticides and nitrates. The recently enacted Water Quality Act of 1987 places, for the first time, a major policy emphasis on controlling agricultural nonpoint-source pollution. The USEPA and U.S. Department of Agriculture (USDA) have recently issued major policy statements and strategies dealing with agricultural chemicals and ground-water quality. The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) has been resubmitted numerous times to meet the demands for protection from hazardous chemical exposure.

The implications of these policy activities has yet to be fully determined, but American agriculture can be expected to undergo changes in production options as tillage practices, chemical choices, and use patterns are restricted or controlled. If we assume that controlling agricultural ground-water contamination implies regulations such as these that focus on restricting chemical applications and tillage practices, it follows that research needs to consider alternative agriculture systems. Interest in low-input or sustainable agricultural systems is increasing as farmers react to the changes which could be imposed on them in the coming years. Low input agriculture, which substitutes tillage, legumes, biological pest control, and crop rotations in place of chemicals in farming practices is a means of reducing nonpoint-source of water pollution. More current studies focus on the agronomic effects of reducing agricultural chemicals and using other synthetic or mechanical

practices. Various forms of these practices have been call "Best Management Practices," "Integrated Pest Management," "Organic Farming," "Sustainable Agriculture," and "Low-Input Agriculture." The specific definitions of each practice varies, and in many cases definitions are overlapping.

2. Contribution to Problem Solution.

The general purpose of low-input agriculture is to combine various farming practices that reduce chemical applications, soil erosion, and soil nutrient depletion. Control of chemical application includes appropriate timing of chemical applications, reduction in the quantity and variety of chemicals used and in some cases the elimination of chemical use entirely. Through these controls, supporters of low-input agriculture feel they may be able to reduce health hazards and production costs while maintaining profits.

3. Objectives.

The objectives of this research are to:

(a) identify technical, institutional, and financial barriers to the adoption of low-input agriculture as a ground-water protection strategy;

(b) estimate the effectiveness of the adoption of low-input agriculture in protecting ground-water quality in a case study context;

(c) design alternative strategies to reduce barriers to the adoption of low-input agricultural methods; and

(d) estimate the first-round effects on farm income, land and water uses, Government revenues, cost of chemicals, and pollution resulting from widespread adoption of low-input agriculture.

4. Approach.

The methods to be used in this project will include (a) selection of a case study, (b) using a mathematical programming model and production budgets for conventional and low-input agriculture, determining of financial barriers to the adoption of low-input agriculture, (c) estimating of ground-water loading for various conventional and low-input agricultural systems, (d) surveying low-input and conventional farmers as to perceived barriers to adoption of low-input agriculture, (e) identifying of barriers and designing strategies to reduce these barriers, and (f) using existing physical models and the mathematical programming model to estimate effects of the alternative strategies.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1730

PROJECT TITLE: Incorporating Public Preferences in the Optimization of Urban Water Supply Reliability: Planning Procedures and Survey Techniques

PERFORMING ORGANIZATION: University of Colorado

PRINCIPAL INVESTIGATOR: C. Howe

DURATION: June 1989 to December 1990

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

The problem is to determine the water-using public's preferences for urban water supply reliability and to incorporate those preferences in urban water-system design and planning. System costs in the western United States escalate sharply with the design level of realiability, as does the required portfolio of raw water holdings (rights), resulting in higher service charges and the denial of reliable water supplies to other sectors, especially local agriculture and environmental applications. The solution is to use contingent valuation methods (interviews and mail surveys) to measure the preferences of water users, water system managers, and elected city officials, to explain observed differences, and to show how an informed public's preferences can be incorporated in system planning.

2. Contribution to Problem Solution.

The solution is to design and test procedures for eliciting the preferences for urban water supply reliability of sub-groups of the water using public, elected public officials (city council), and professional water managers. Procedures will then be designed to incorporate the public's informed preferences in the selection of an appropriate level of reliability.

3. Objectives.

The objectives of this research are to determine:

(a) excessive risk aversion on the part of public water managers;

(b) causes of different preferences among water users, water officials, and public officials (principal-agent problems);

(c) the effects of system cost, user fee, and shortage damage information on public preferences;

(d) differences between "willingness-to-pay" for higher reliability and "willingness-to-accept" (compensation) for lower reliability (a major area of theoretical controversy in economics).

4. Approach.

To design, pretest, and use interview and mail surveys to determine preferences for reliability. To incorporate the resultant "willingness-to-pay" measures in optimizing system reliability. To prepare a handbook on these techniques for the use of public officials and water interest groups.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1736

PROJECT TITLE: Facilitating Voluntary Transfers of Bureau of Reclamation-Supplied Water

PERFORMING ORGANIZATION: University of Colorado

PRINCIPAL INVESTIGATOR: L. MacDonnell

DURATION: June 1989 to June 1990

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

The present level of interest in the voluntary transfer of water is high throughout the western States. Available surface-water supplies in many basins of the West are fully allocated. Construction of additional storage appears limited by a number of factors, one of which is the decrease in Federal funding support. Federally financed Bureau of Reclamation projects now represent a major part of the storage and delivery system in the western States. How to permit some voluntary reallocation of the water supplies available in this system to meet new needs without unduly impairing existing interests is of interest to the Federal and nonfederal managers of these systems, the present users of this water, the prospective users of this water, and all those concerned about making more efficient the utilization of the West's limited water supplies.

2. Contribution to Problem Solution.

The research project will provide a detailed evaluation of transfer activities involving shifts of Bureau-supplied water from agricultural to nonagricultural uses in six western States --Arizona, California, New Mexico, Utah, and Wyoming.

3. Objectives.

The objectives of the research are to:

(a) summarize and analyze the existing legal and institutional impediments affecting voluntary transfers of Bureau of Reclamation supplied water;

(b) ascertain and evaluate perceptions regarding transfers of Bureau supplied water -- are there limitations on such transfers and, if so, what are they?

(c) determine from an analysis of selected cases involving successful, unsuccessful, and pending transfers the significance of identified limitations;

(d) identify policy options at the Federal, State, and district level for promoting voluntary transfers while protecting legitimate existing interests; and

(e) organize and present a symposium presenting and discussing these options.

4. Approach.

We will build on work presently underway which will compile data concerning the major Bureau projects in six western States. Through an examination of the literature, we will identify possible legal and institutional uncertainties affecting transfers. Through an extensive interviewing process, we will test perceptions of key participants--Bureau of Reclamation officials, water district representatives, water users, potential and actual water buyers, and others--concerning the significance of these factors. Simultaneously, we will search for alternative or additional factors viewed as having an important effect on the transferability of such water. We will select several case examples involving successful, unsuccessful, and pending or proposed transfers for detailed evaluation. Based on our findings, we will propose policy and administrative options for facilitating voluntary transfers while protecting important interests. The final report will provide the basis for a symposium to present and discuss our findings as well as other points of view.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1742

PROJECT TITLE: Institutional Options for Conjunctive Management of Ground and Surface Water in the Western United States

PERFORMING ORGANIZATION: University of Arizona

PRINCIPAL INVESTIGATOR: W. Lord, T. Maddock, S. Sorooshian, and M. Bradley

DURATION: July 1989 to June 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Allocation and management of surface water and ground water in the western United States generally follow different sets of institutional rules (the doctrine of prior appropriation and the common law rule of reasonable use, respectively, to over-generalize). These two sets of rules are different, and are said to make it impossible to manage the two kinds of resources conjunctively, as their close hydrologic interrelationship makes desirable. However, little systematic information exists which would clearly delineate the dimensions of this problem or what can be done to overcome it.

2. Contribution to Problem Solution.

The research would provide specific information on conjunctive management problems and their institutional implications. It would define those water allocation and management rules which are effective in attaining water-policy objectives under various combinations of hydrologic and water demand conditions.

3. Objectives.

The objectives are to determine under what prevailing combinations of hydrologic and institutional circumstances surface- and ground-water resources can or cannot be managed conjunctively, and to describe institutional improvements which could be considered to achieve conjunctive management.

4. Approach.

The project would combine institutional and hydrologic information within an analytical structure designed to reveal under what institutional and hydrologic circumstances conjunctive management is occurring or is not occurring within the six States of Arizona, Colorado, New Mexico, California, Utah, and Wyoming, given the water-management objectives established by those States. It would reveal what specific water-allocation rules are effective in achieving conjunctive management, and thus should be considered for adoption. The project would use hydrologic models and institutional analysis within an overall framework of multicriterion decision making.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1746

PROJECT TITLE: State Revolving Loan Funds: Analysis of Institutional Arrangements and Distributive Consequences

PERFORMING ORGANIZATION: Auburn University

PRINCIPAL INVESTIGATOR: J. Heilman and G. Johnson

DURATION: June 1989 to May 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

The Water Quality Act (WQA) of 1987 provides for the transfer of wastewater programs, including program management and wastewater treatment works (WTWs) construction financing, from the U.S. Environmental Protection Agency (USEPA) to the State level. Through the policy and institutional framework of State Revolving Funds (SRFs), States will assume responsibility for the management and allocation of billions of national and State dollars dedicated to water-quality projects. To date, five States have executed agreements to implement SRFs. The remaining States are in varying stages of developing agreements to participate in the program. The institutional and financial arrangements adopted to implement and administer the SRFs are and will be a critical factor in determining how productive SRFs will be in meeting the water-quality needs in each State. At this point, the SRF transition and implementation processes in each State are confronted with major uncertainties, seemingly conflicting or ambiguous requirements, the absence of systematically developed institutional, financing, and implementation models, and an absence of analyses of consequences of varying institutional arrangements on overall water-quality management capability and distributive impacts. The 50 States differ substantially in terms of water-quality management capability, experience with loan funds, and perceptions of the issues and consequences involved in establishing SRFs. This study will address State level issues and options through a 50-State survey, selected case studies, and economic modeling.

2. Contribution to Problem Solution.

The institutional arrangements selected for SRF implementation affect both distributional outcomes and water-quality management capability. To maximize the ability of SRFs to meet water-quality management objectives, the research will provide systematic information, analysis, and recommendations for policy makers. To achieve sustained progress in meeting State water-quality needs efficiently and productively, it is imperative that these issues be addressed and the results be made available to the States at the earliest possible time. The results of the study will respond to distributional and management issues related to State level responsibility and ability to meet the documented need for continued water-quality programs. It will produce

conclusions and recommendations concerning the distributive consequences of alternative institutional arrangements in SRF implementation. Also, it will include representative case studies providing estimates of economic efficiency gains and the distributive consequences from institutional changes.

3. Objectives.

The objective is to measure and evaluate the efficiency and effectiveness, in terms of distributional outcomes and water-management capability, of different institutional arrangements of SRF implementation.

4. Approach.

The research uses four approaches to achieve the objectives: (a) it analyzes data from sources including legislation, legislative history, regulatory documentation, USEPA's national data bases, and a 50-State survey of State regulatory agency officicals and other policymakers; (b) case studies will be conducted of alternative SRF institutional arrangements and financing models as identified in the survey; (c) economic analyses will be made of these SRF models in terms of relative efficiency, net benefits, and distributive consequences; (d) based on the data collected through approaches (a) and (b), analysis will be conducted of SRF policy implementation. The analysis will focus on interorganizational and intergovernmental institutional arrangements and processes involved in the transition from a national program to State-level SRFs. The analysis will assess the implication of these for the adoption and implementation of alternative SRF institutional arrangements and financing models.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1748

PROJECT TITLE: Special Water Districts: A Tool for Water-Quality Management as Well as Economic Efficiency

PERFORMING ORGANIZATION: University of South Dakota

PRINCIPAL INVESTIGATOR: J. Davidson

DURATION: July 1989 to June 1990

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Amending the Clean Water Act in 1987, Congress stated that to the maximum extent practicable States should try to solve nonpoint-source and ground-water pollution problems on a watershed-by-watershed basis. Until now, organization of legal entities which conform to natural watershed boundaries has been used only to develop water resources for such economic purposes as irrigation, drainage, and municipal supply. This research will study the legal and policy feasibility of adapting the watershed district to the control of soil erosion, nonpoint source and ground-water pollution. This research approach will be a library-based legal and policy analysis.

2. Contribution to Problem Solution.

This topic has not been addressed in the literature of water-quality management. The research will seek to articulate a practical way to use special district laws to achieve pollution control purposes.

3. Objective.

The objective of this project is to determine whether it is practical to use watershed districts, organized along watershed boundaries, to solve water pollution problems. If legal and practical feasibility is found to exist, such districts could be used to organize responses to the presently intractible regulatory problems of controlling nonpoint-source and ground-water pollution.

4. Approach.

The first task will be to examine the special district laws in all 50 States. This examination will look for two things: (1) watershed laws that deal specifically with water pollution control; and (2) districts which are in fact operating with a goal of water pollution control. A second task will be to communicate by mail and telephone with any district which claims a pollution control purpose. This communication will be aimed at isolating key legal and policy issues for subsequent analysis. A third task will be a library search for literature dealing generally with special districts (there is no known literature dealing with the specific topic of this project). The goal here will be to locate analysis which will be useful, by analogy, to the final report on this proposal.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1750

PROJECT TITLE: Impacts of Agricultural Production Practices on the Quantity and Quality of Ground Water in the Central High Plains

PERFORMING ORGANIZATION: Oklahoma State University

PRINCIPAL INVESTIGATOR: H. Mapp, D. Bernardo, J. Nelson, R. Elliott, and J. Stone

DURATION: August 1989 to August 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Growing concern over ground-water quality and the impact of agricultural practices on that quality has prompted regulatory activities that will significantly influence agricultural production in many regions, including the Central High Plains. Policies aimed at controlling agricultural-source pollution will serve as important determinants of production practices and technologies employed in the region, as well as influence the profitability and/or sustainability of agricultural production. Although significant ground-water legislation appears eminent, little research has been conducted to assess the economic impact of regulation. This study will develop and apply a regional economic model to project the impact of various policy alternatives on agricultural chemical use, ground-water quantity and quality, and returns from agricultural production.

2. Contribution to Problem Solution.

This project will provide estimates of the economic and water-quality impacts of various ground-water policy alternatives over a multi-year planning horizon. The approach will integrate the most current information concerning agricultural chemical use, tillage practices, irrigation practices, technology alternatives and their relationship with ground-water quality into the economic assessment of water quality policies. Accurate estimates of these policy impacts are essential information for policymakers involved in the development of ground-water quality legislation.

3. Objectives.

The objectives of this research are to:

(a) identify, for the area over the Central High Plains aquifer, subregions based on soil and water resource considerations, and natural factors which favor ground-water contamination from agricultural practices;

(b) for each subregion, identify relevant agricultural tillage and irrigation practices and technologies, and establish the relationship between practices and movement of agricultural chemicals through the plant root zone;

(c) construct a model to project rates of adoption of tillage and irrigation practices and technology under alternative water-quality policy schemes;

(d) estimate the impact of policy alternatives on rates of adoption of tillage and irrigation practices and technology and the quality and quantity of ground-water within the Central High Plains aquifer; and

(e) disseminate information to farmers and policymakers identifying and evaluating agricultural practices which conserve water and reduce the likelihood of ground-water contamination in the region.

4. Approach.

A mathematical programming model of the agricultural sector overlying the Central High Plains aquifer will be developed to estimate the economic impact of alternative ground-water quality regulation and polices. Application of the model will provide estimates of the impact of ground-water policy alternatives on agricultural chemical use, movement of chemicals through the plant root zone, rates of technology adoption, ground-water withdrawals, and producer income over the time horizon of the analysis. Such an approach will be innovative from a methodological standpoint, providing an approach which could be used in other regional analyses focusing on the relationship between agricultural practices and water quality.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1751

PROJECT TITLE: Management of Conserved Water--Market Development, Efficiency Gains Distributive Consequences

PERFORMING ORGANIZATION: University of Arizona

PRINCIPAL INVESTIGATOR: B. Colby, W. Martin, and H. Ayer

DURATION: September 1989 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Transfers of conserved or salvaged irrigation water generate substantial controversy in the western States. Proponents argue that agricultural water conservation can generate substantial water savings which could then be made available to rapidly growing cities and industry and used to enhance instream flows for recreation, fish and and wildlife (Weatherford, Frederick). This optimistic view of the potential for easing western water shortages by using agricultural conservation is reflected in the popular press as well (U.S. Water News, Smith and Vaughn). On the other hand, western State water agencies and courts have taken a firm stand against transfers of conserved water, with the exception of Oregon and California. In these two States, new legislation specifically allows transfer of conserved water. However, no such transfers have occurred and these States do not yet have clear criteria for evaluating proposals to transfer conserved water. Most western States have specific policies against such transfers, based on the belief that transfers of conserved irrigation water impair downstream water users. Are there significant economic efficiency gains from transfer of conserved irrigation water? What are the costs, the benefits, and who is likely to gain or be harmed? Policymakers, public agencies, irrigators, municipalities, and other water interests could benefit from a careful analysis of these questions.

2. Contribution to Problem Solution.

Policymakers presently lack objective information on the desirability of markets for conserved water. There has been no research to date that addresses the economic, legal, and engineering issues in an integrated manner, as this project does. This research will provide information on which policy decisions regarding agricultural water conservation and market development can be based.

3. Objectives.

The objectives of this research are to:

(a) determine whether the benefits of agricultural water conservation and transfer of conserved water outweigh the costs of such transfers, and further, to identify the groups most likely to benefit and those who might be impaired and incur costs as a result of tranfers; and

(b) identify the legislative and administrative policy changes necessary to facilitate low cost transfers of conserved water for western States and Federal agencies wishing to encourage the development of markets for conserved water.

4. Approach.

Costs, benefits and third party impacts of agricultural water conservation and transfer will be evaluated for key areas of the Colorado River Basin. A four-State (California, Oregon, Colorado, and Arizona) cross-section of policies regarding transfers of conserved water has been selected for the institutional analysis.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1752

PROJECT TITLE: An Economic Evaluation of Water Marketing in a Low Transaction Cost Setting

PERFORMING ORGANIZATION: Texas A&M Research Foundation

PRINCIPAL INVESTIGATOR: R. Griffin

DURATION: September 1989 to August 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Available information on the economic efficiency of water markets is primarily theoretical or descriptive. Available quantitative research does not examine economic efficiency. Empirical evidence is needed, especially as revisions to State and Federal institutions are under consideration. A critical problem element concerns methods of structuring water markets so that third party impacts and public good characteristics are recognized. Increased protection of these interests raises market transaction costs and thereby restricts market activity.

2. Contribution to Problem Solution.

This research measures the benefits and costs of actual water market transactions occurring in Texas. Such information assists policy deliberations by evaluating the economic implications of an existing market structure. An examination of Texas water marketing is particularly useful because the low burdens placed on Texas transactors leads to a relatively unrestricted market. This situation offers a unique opportunity to investigate the distribution of marketing benefits and costs.

3. Objective.

The goal of this research is to perform a complete benefit-cost appraisal of a broad set of recent water market transactions and thereby obtain evidence on how a promarket rule structure impacts transactors and third parties.

4. Approach.

The general methodology is to identify the many influences of selected 1980-88 water transactions and to then quantify these economic impacts. Methods of evaluating individual impacts include, but are not limited to, surplus measurements, dual values from agricultural programming studies, contract terms, contingent valuation results, and direct inquiries of affected parties.

CLIMATE AND HYDROLOGY

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1725

PROJECT TITLE: An Integrated Tracer and Hydrometric Investigation of Hydrologic Flowpaths and Streamflow Generation

PERFORMING ORGANIZATION: Massachusetts Institute of Technology

PRINCIPAL INVESTIGATOR: H. Hemond

DURATION: June 1989 to May 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Adequate knowledge of the pathways followed by water as it moves through the watershed to the stream network is needed to model the transport and fate of chemical constitutents deposited in headwater areas. Currently, there is no scientific concensus on this issue, and direct contradictions, even between findings of different recent studies of the same watershed, can be found. This situation poses acute limitations on present models of watershed response to deposition of acidic contaminants, as well as to the ability to model the fate and transport of point-source contaminants on upland watersheds.

2. Contribution to Problem Solution.

This research will provide a quantitative assessment of water pathways on a study site that is typical of many watersheds in the glaciated northeast, with the expectation that the integrated tracer/hydrometric methods and many of the conclusions can be readily transferred among similar watersheds in North America.

3. Objectives.

The objectives of this project is to provide a complete descriptors of streamflow generation on a forested, glaciated watershed in central Massachusetts and develop an integrated tracer and hydrometric method that is transferable to other sites.

4. Approach.

Numerous significant contributions to hillslope hydrology have been made during the past two decades, but most workers have used either physical or tracer techniques. This study will impose additional constraints on determining the pathways of water by using hydrometric techniques that are capable of providing synoptic physical data at the necessary high temporal resolution, simultaneously with Radon-222, a tracer whose use we have devloped at our site, and classical tracer isotopes and chemicals (^{18}O, D, Cl^-).

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1731

PROJECT TITLE: Applications of Statistical Methods to Study Climate and Flooding Fluctuations

PERFORMING ORGANIZATION: University of Illinois

PRINCIPAL INVESTIGATOR: K. Kunkel and S. Changnon

DURATION: July 1989 to June 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Recent work has identified the existence of sizeable climatic fluctuations in the central United States during the past 60 years. These fluctuations may have affected the frequency, duration, and/or intensity of floods during that period. Such changes in flood characteristics could have serious implications for the design and operation of water systems. In addition, an understanding of how climatic fluctuations in the past have affected flood characteristics is a necessary prelude to predicting the hydrologic consequences of future climate change.

A recent pilot study has detected a relation between recent climate fluctuations and changes in flooding characteristics for Illinois. These results indicate that a study broader in scope needs to be undertaken. This study will investigate a multi-State region in the central United States and employ sophisticated statistical techniques to analyze the relation between long-term daily streamflow and precipitation. Both temporal and spatial patterns of changes in these relation will be investigated.

2. Contribution to Problem Solution.

Long-term records of daily streamflow and daily precipitation data for numerous basins in the central United States will be systematically analyzed using modern statistical techniques. This work will identify the relevant shifts in climate that occurred during 1921-85. The effect on flood characteristics will be identified. Any spatial differences in these climateflood characteristics will also be identified.

3. Objectives.

The objectives of this research are to:

(a) identify temporal fluctuations in flood characteristics in the Midwest for the period of 1921-1985;

(b) identify temporal fluctuations in climate variables related to flooding for the same period; and

(c) determine the relation between changes in flood characteristics and changes in climatic variables.

4. Approach.

The time series of flood characteristics and of selected climatic parameters will be subjected to a variety of statistical techniques to evaluate the characteristics of the time series, to detect significant temporal changes, and to determine relation between the time series.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1732

PROJECT TITLE: Turbulence Measurements in a Meandering-Channel Laboratory Channel

PERFORMING ORGANIZATION: University of Texas

PRINCIPAL INVESTIGATOR: E. Holley

DURATION: September 1989 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

The turbulent characteristics of open channel and river flows are extremely important because of the fundamental influence of turbulence on the flow itself and also because of the engineering processes and problems (sediment transport, pollutant transport, volatilization of dissolved toxics, etc.) which are affected by the turbulence. Turbulence information also is needed to develop numerical techniques that properly represent the turbulence in modeling flows (even time-averaged flow characteristics). In spite of the importance of turbulence and of river flows, there has been no comprehensive study of the turbulence characteristics of flow in a meandering channel. Turbulence data will be collected in a large, unique meandering-channel laboratory river which maintains the essential geometric and dynamic features of actual meandering rivers.

2. Contribution to Problem Solution.

This research will provide the most comprehensive data set on turbulence in meandering channels with natural cross sectional variations, on how turbulence is produced and redistributed in the flow, and on how the turbulence influences the flow. Analysis of the data will provide new insights into the flow in rivers and will provide a data base for development and testing of numerical schemes.

3. Objectives.

The primary objectives are to measure and analyze the turbulence characteristics throughout a meandering simulated river flow for two types of boundary roughness. As an aid to evaluating the influence of transverse bed slope, similar measurements and analysis will also be done for turbulence in a straight flume with a transversely sloping plane bed.

4. Approach.

Turbulence measurements will first be made in a straight flume with a false floor having a transverse bed slope. These tests will be used to evaluate the effects of transverse shear on turbulence in open channel flows. Measurements will then be made throughout the depth, width, and length of the

meandering channel. The data will include longitudinal, lateral, and vertical turbulent velocity fluctuations with associated root-mean-squared values, auto-correlation functions, energy spectra, terms in the turbulent energy balance, and Reynolds stresses.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1737

PROJECT TITLE: Modeling of Seasonal Intermittent Hydrologic Processes

PERFORMING ORGANIZATION: Colorado State University

PRINCIPAL INVESTIGATOR: J. Salas and D. Boes

DURATION: September 1989 to February 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Planning and operational studies of water-resources systems which are located in arid and semi-arid regions are normally based on hydrologic data, such as monthly precipitation and streamflow, which are seasonal, correlated and intermittent. If synthetic hydrology is to be used for such studies, then a suitable procedure must be used to analyze, model and generate such synthetic intermittent events. Although standard procedures already exist applicable to hydrologic processes of humid and temperate regions, this is not the case for processes in arid and semi-arid regions. In these dry regions, hydrologic data such as streamflow include a number of zero flows. This feature makes the standard procedures such as those based on autoregressive models inapplicable. The research herein addresses specifically the analysis and modeling of intermittent hydrologic processes.

2. Contribution to Problem Solution.

The research offers the possibility of approaching the problem in a more realistic manner than has been done before. We will use a modeling scheme and estimation procedure which by its very nature will be able to capture those characteristics which are important of intermittent hydrologic phenomena. It is expected that this research will improve the accuracy of prediction of precipitation and streamflow in dry regions of the United States.

3. Objectives.

The specific objectives of the research are to:

(a) document data and corresponding statistical characteristics of intermittent processes such as annual and seasonal precipitation and streamflow for single and multiple sites in selected dry regions of the country;

(b) develop single site and multisite models and estimation procedures which can be applicable to model and generate time series of annual and seasonal intermittent hydrologic processes;

(c) test and apply proposed models and approaches based on a number of selected data which will be gathered for this research. Likewise, comparisons of proposed models with existing approaches will be made; and

(d) document and make available to the public the software concerning the models and procedures to be developed in the study.

4. Approach.

The research will consist of three phases. The first 6 months will consist of gathering a number of intermittent water-resources time series such as monthly and annual precipitation and streamflow series of semiarid and arid regions, and analyzing in detail the stochastic characteristics shown by the historical data. Such historical characteristics will be used in testing the models and procedures to be developed in subsequent tasks. In addition, further literature search will be made concerning the topic. The next phase will cover a 12-month period and will include the development and testing of single site models for intermittent seasonal precipitation and streamflow series. Appropriate estimation techniques will be developed and applied such as the methods of moments and maximum likelihood. Testing will be based on data generation. The final phase will cover the last 12 months of the project. It will consist of developing and testing a multisite model for representing intermittent seasonal precipitation and streamflow series. Appropriate estimation techniques will be developed and applied.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1743

PROJECT TITLE: Study of Model Hydrological Cycle of North America in a Version of the National Center for Atmospheric Research's General Circulation Model

PERFORMING ORGANIZATION: University of California

PRINCIPAL INVESTIGATOR: J. Roads and J. Namias

DURATION: September 1989 to August 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Natural variations of the climate system and possible future changes are both supposed to have strong influences on the hydrology over North America, although effects of atmospheric forcing on the hydrology are not completely understood. Precipitation is affected by the atmospheric circulation on time scales from a few days to decades, but its influence on other components of the surface hydrology such as runoff, soil moisture, snow cover and evaporation and their interrelationships have not been thoroughly studied at individual regions. Mechanisms responsible for hydrological extremes and extended wet and dry spells over this wide range of time scales are not well understood and hence such extremes are poorly predicted. With the increasing demand for water in the United States, future variations in these hydrological variables will become increasingly important.

2. Contribution to Problem Solution.

This research will address the problem in a study of the atmospheric influence on hydrological variability using a seasonal cycle version of the National Center for Atmospheric Research (NCAR) general circulation model (GCM). Because all of the components in the surface-water balance are not well observed, and because atmospheric GCMs offer a numerical laboratory to simulate the large scale weather and climate variability, it is important to evaluate and improve the performance of GCMs in simulating the mean and anomaly characteristics of the surface hydrology as well as use the variability prescribed by the GCM to understand the interactions of weather and climate variability on the hydrology.

3. Objectives.

The model circulation, temperature and hydrological variability will be compared with observations to evaluate and possibly improve the model and used to better understand the influcence of short period climate variability on hydrological fluctuations. GCM's have demonstrated the ability to simulate some of the broad scale features of surface hydrological variables, and there is great need to evaluate detailed spatial and temporal variabiality over individual regions and to examine the interrelationships among these variables.

4. Approach.

The research will compare daily, monthly, seasonal and interannual observed and modeled variations with appropriate statistical tests. The phase lag between model runoff and precipitation for both the mean and annual cycles and the anomalous components will be compared with observed streamflow versus precipitation at selected climatic regions in North America. (Analogous model runoff-precipitation relationships from other continents may be examined for comparison and better reliability.) The realism of model snow pack and its participation in the precipitation-runoff process will also be examined. In addition, the spatial and temporal structure of the model hydrological components and their relationship to large scale anomaly patterns of the model atmospheric circulation and their resemblence to those seen from observations will be examined.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1753

PROJECT TITLE: Development of a Macro-Scale Land-Surface Hydrologic Model for General Circulation Models

PERFORMING ORGANIZATION: Princeton University

PRINCIPAL INVESTIGATOR: E. Wood

DURATION: September 1989 to August 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

Correctly modeling the land-surface hydrology is critical for the accurate modeling of the global water and energy balances with general circulation models (GCMs). The important links between soil moisture and atmospheric circulation have been recognized for over 30 years, yet the current formulations suffer a number of major problems which include sub-grid spatial heterogeniety and its influence on process averaging, and the need for computational efficiency. The increased interest in analyzing the water resource impacts due to climate change from the greenhouse gas effect requires that better GCMs for land hydrology formulations be developed. Such improved formulations will lead to improved modeling of climate impacts.

2. Contribution to Problem Solution.

The results will be useful for GCM modelers developing improved models of global water balance dynamics and atmospheric circulation, for hydrologists interested in large scale water balance dynamics and modeling land-surface hydrologic processes, and for hydrologists and water-resources planners interested in assessing the hydrologic impacts due to climate change.

3. Objective.

The objective of the research is the development and evaluation of a new formulation for land-surface hydrology appropriate for inclusion in GCMs The new formulation will be compared to current formulations currently embedded within the Geophysical Fluid Dynamics Laboratory (GFDL) GCM, and the Goddard Institute for Space Studies (GISS) GCM, as well as the detailed water balance model developed by the principal investigator through related research.

4. Approach.

Time series of water balance fluxes at the GCM grid scale will be created by aggregating point water balance fluxes modeled by the detailed water balance model. The detailed model will incorporate spatial variability in soils, topography, vegetation, and rainfall. This time series will be used to investigate the performance of the proposed formulation and the current GFDL and GISS formulations.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1754

PROJECT TITLE: Hydroclimatic Regionalization of Flooding Variability: A Combined Climatic-Stochastic Approach

PERFORMING ORGANIZATION: Louisiana State University

PRINCIPAL INVESTIGATOR: K. Hirschboeck, J. Cruise, V. Singh, and R. Muller

DURATION: August 1989 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems and Problem Solution Approach.

In the wake of the major El Nino-Southern Oscillation (ENSO) event of 1982-83, the role of climatic variability in generating anomalous and widespread floods has become a source of growing concern among those who seek to predict reliable future estimates of peak flows in both gaged and ungaged basins. In addition, increased attention by the scientific community has been focused on the global consequences of a climatic response to rising CO_2 levels and other "greenhouse effect" gases. In each case, a better understanding of how the surface-water component of the hydrologic cycle responds to large scale changes in atmospheric circulation is needed. However, coincident with this growing concern for a better understanding of the surface-water response to climatic variability, streamflow data-collection networks have had to be reduced for budgetary purposes at both the Federal and State levels. This dilemma is compounded by a growing population's demand for increasingly reliable estimates of future water supplies and flood hazards and more responsible and cost-effective water resources and floodplain management.

Regionalization techniques of flood estimation have emerged as effective solutions for reducing the uncertainty inherent in short systematic records and diminishing data networks, but little attention has been focused on the physical factors controlling the statistical distributions of floods at sites that are grouped together in the regionalization process. In particular, no attempts have been made to evaluate the uncertainty imparted to systematic records by the occurrence of anomalous and/or persistent flood-producing atmospheric circulation patterns that are part of either naturally occurring decadal-scale climatic variations or anomalously occurring large-scale circulation adjustments, reflective of major global climatic changes. Climatic variability can be considered the "ultimate" source of all flooding variability because the variability imparted to a catchment by climatic events precedes any subsequent variations in runoff that may arise in the basin itself due to physiographic or land use properties. To develop reliable flood estimates under both present and potentially changing future climatic regimes, it is therefore important that an improved understanding of the link between climatic and hydrologic variability be developed, especially in terms of varying large-scale atmospheric circulation patterns and regional flood frequency variations.

2. Contribution to Problem Solution.

The aim of this research is to integrate traditional hydrologic regionalization techniques for flood analysis with variations in large-scale atmospheric circulation patterns. Regional flood frequency analysis has emerged as a viable solution to the problem of reliable flood prediction when faced with relatively short systematic records, ungaged watersheds, or reduced data-collection networks. In most regionalization methods, the main climate-related basin characteristics involved in the determination of a homogeneous region are average values of precipitation or storm intensity. Little attention has been given to the spatial and temporal dynamics of seasonal or long-term variations in the large-scale atmospheric circulation patterns that ultimately generate event at a site.

3. Objectives.

The objectives of this research are to:

(a) group selected U.S. Geological Survey (USGS) gaging stations in Arizona and Louisiana into hydroclimatically homogeneous regions on the basis of similar at-site-flood-generating atmospheric processes and similar regional responses to specific large-scale circulation patterns;

(b) derive at-site probability distributions from hydroclimatically separated series of observed flood data;

(c) derive hydroclimatically based regional probability distributions from the at-site distributions developed in (b); and

(d) define the relation between large-scale atmospheric circulation patterns and the regionalized stochastic hydrologic response, and to use this relation to develop regional flooding situations that might occur in response to shifting global climatic patterns.

4. Approach.

Our approach will be to regionalize the flood series recorded at gaging stations in Arizona and Louisiana by emphasizing their hydroclimatic properties in addition to their basin characteristics. Hydroclimatic similarity will be determined by peak flow and precipitation data, synoptic weather maps, composite upper air circulation anomaly maps, and correlation fields. At-site annual distributions for each watershed will be determined by applying the Poisson partial duration flood model to mix the marginal distributions of climatically similar flood series. These watersheds will then be grouped into their defined hydroclimatically homogeneous areas and regional distributions will be determined for each area using the indexing method introduced by the USGS. The statistical properties of the regional distributions in each State will be compared and the large-scale atmospheric circulation patterns most closely linked to flooding in each hydroclimatic region will be defined and used to develop situations of flooding response to projected shifts in the global atmospheric circulation.

SECTION II

SUMMARIES OF PROJECTS COMPLETED

IN FISCAL YEAR 1989

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1301

TITLE: Water Purification and Waste Concentration by the Vacuum Freezing Multiple Phase Transformation Process and its Eutectic Extension

PERFORMING ORGANIZATION: Calyxes Research and Development Corporation

PRINCIPAL INVESTIGATOR: C. Y. Cheng

START: September 1986

FINAL REPORT RECEIVED: September 1988

ABSTRACT:

This study, under U.S. Geological Survey (USGS) grant number 14-08-0001-G1301 entitled "Water Purification and Waste Concentration by the Vacuum Freezing Multiple Phase Transformation (VFMPT) Process and its Eutectic Extension," is a continuation of USGS grant number 14-08-0001-G1131 for the study of the VFMPT process for desalination and water reuse. During the first grant period, bench-scale experiments were completed for the VFMPT Process and initial design of a prototype VFMPT plant was completed. Several key components of the system were tested mechanically. In addition, it was discovered that vacuum freezing also can be used to separate eutectic mixtures so that solvent and solute can be separated as distinct solids.

During the course of the second grant, the vacuum freezing and vapor liquefaction operations were tested in a proptotype unit referred to as the "40-Inch Long" unit with freezing rates determined. The two-step vapor liquefaction operation consisting of vapor desublimation and desublimate melting was conducted continuously using multiple condensers operating in sequence. Several designs were tested for circulating feed liquid to create surface area for evaporative freezing to take place. After the course of the grant period, it was concluded that a twin screw system half submerged in the pool would be a energy efficient method for providing the necessary surface area. Feeding of slurry from the vacuum freezer to the slurry pump, and slurry pumping from vacuum to ambient pressure for crystal washing also were successfully demonstrated using a discflow pump. The pumping of slurry from vacuum to ambient pressure allowed for crystal washing and melting to take place at ambient pressure. After the course of the grant, it was discovered that a rotating lobe pump could accomplish slurry pumping with much less energy input than the discflow pump required.

In addition, a new "Mini-Quad" pilot plant was assembled using twin screws in the freezer, a lobe slurry pump and a four cylinder condenser design. The operation of this pilot plant using a liquid overfeed freon refrigeration system which rejects heat to ambient has been successful. A wash column has

been assembled together with the Mini-Quad, and crystal washing at ambient pressure has performed satisfactorily.

A flowsheet was developed for the VFMPT plant with detailed mass and energy balances and energy requirements determined. For seawater desalination with 50-percent recovery of freshwater, the energy input required for the VFMPT process is from 42 to 52 kw-hr/kgal of product water, depending on the efficiencies of refrigerant compressors. Installed plant cost for a 1 million gal/d VFMPT desalination plant is about $2.85 million.

A flowsheet was also developed for the treatment of oil-well brine, simulated by a 6-weight-percent sodium chloride solution. The energy requirement calculated for a VFMPT/primary refrigerant eutectic freezing combination, which recovers 90 percent of the feed water as freshwater and the remainder as sodium chloride dihydrate, is about 70 kw-hr per 1000 gallons of feed. An additional operation allows for the recovery of salt in completely dry form.

The main tasks required for completing the demonstration of the Mini-Quad VFMPT pilot plant are the thermal coupling of the ice-melting operation with the desublimation operation and the addition of the necessary process controls. A third pilot plant is being constructed using ammonia liquid overfeed refrigeration and a low compression ratio ammonia blower to accomplish heat reuse. The use of ammonia will greatly increase the heat transfer rates. Twin screws also will be used in this unit so that all of the necessary components for a commercial design will be tested in this system.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-220891/AS

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1143

TITLE: Hydrological Sampling: A Characterization in Terms of Rainfall and Basin Properties

PERFORMING ORGANIZATION: Massachusetts Institute of Technology

PRINCIPAL INVESTIGATOR: Rafael L. Bras

START: September 1985

FINAL REPORT RECEIVED: November 1988

ABSTRACT:

This report considers the sampling of rainfall and runoff processes, both in time and in space, and links the sampling problem to basin and rainfall characteristics. Sampling strategies are defined by the number of rain gages, rainfall measurement interval and flow measurement interval. The effectiveness of different sampling strategies is measured by the variance of the error in estimating either the volume or peak of streamflow. This is related to the rainfall and basin rainfall-runoff properties through characterizations of these processes. Several rainfall characterizations, including stationary and non-stationary event based models are used. Runoff from rainfall is characterized in terms of the fluvial geomorphology of the basin. Linear filtering techniques are used to compute the variance of the estimation error for different sampling strategies. The results are given in the form of quasi-general graphs, which can be used to select appropriate sampling options when doing network design.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-132567/AS

PUBLICATIONS:

Bras, R. L., Tarboton, D. G., and Puente, C., 1987, Combined hydrologic sampling criteria for rainfall and streamflow: J. of Hydrology, v. 95, p. 323-339.

Tarboton, D. G., 1987, Hydrologic sampling: a characterization in terms of rainfall and basin properties: report submitted in partial fulfillments, M.C.E. Thesis, Massachusetts Institute of Technology.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1505

TITLE: Assessing the Sensitivity of High Altitude New Mexican Wilderness Lakes to Acidic Precipitation and Trace Metal Contamination

PERFORMING ORGANIZATION: New Mexico Institute of Mining and Technology

PRINCIPAL INVESTIGATORS: Gerald Z. Jacobi, Thomas R. Lynch, Carl J. Popp, and James M. Robertson

START: September 1987

FINAL REPORT RECEIVED: November 1988

ABSTRACT:

Seventeen high mountain lakes in northern New Mexico were sampled to determine their present biological and chemical condition. In addition, sediment cores were collected at each of the lakes to determine trace-metal concentrations, diatom assemblages, and mineralogies as a function of depth. Two of the cores were age-dated using Pb-210 chronology. Water in eight of the lakes had low alkalinities and, therefore, low capacities for neutralization. These lakes were located in basins where the surface geology was dominated by Precambrian rocks. Atmospheric deposition appears to be contributing acid and trace metals associated with human sources to some of the lakes. Trace metal accumulations in the upper layers of Santa Fe Lake began about 60 years ago and about 10 years ago in Truchas Lake. An acid pulse (pH 5.7) associated with snow melt was documented in Santa Fe Lake and corresponds with an observed decrease of Daphnia sp. populations. Pea clam densities also appeared to be low in lakes having low-alkalinity water. Diatom assemblages in sediment from cores from Sante Fe Lake and Truchas Lake appear to be shifing to more acid tolerant species than in the past.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-148456/AS

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1136

TITLE: Biodegradation of Trichloroethylene and Biomanipulation of Aquifers

PERFORMING ORGANIZATION: Princeton University

PRINCIPAL INVESTIGATORS: Peter R. Jaffe, Stewart W. Taylor, Nam H. Baek, P. C. D. Milly, and Andrew C. Marinucci

START: September 1985

FINAL REPORT RECEIVED: November 1988

ABSTRACT:

Three distinct aspects of the biodegradation process in a porous media were addressed here:

(1) The effect of the trichloroethylene (TCE) concentration on bacterial activity was investigated. The results showed that the dissolved phase concentration directly affects the bacterial activity. For aerobic soils LD_{50} for water concentrations ranged between 200-300 mg/l for CO_2 evolution, and 80 to 150 mg/l for dehydrogenase activity.

(2) The degradation of TCE and its intermediates by mixed cultures containing fermenters and methanogens was investigated, Results showed that fermenters play an important role in this process, and that the degradation rate correlates with the methanogenic activity. It was shown that TCE can be degraded by these mixed cultures via 1, 1-dichloroethylene to vinyl chloride, to chloroethane which is readily degradable. Kinetic rates were obtained for this degradation process and normalized with respect to the methane production.

(3) The effect of biomass production in a porous media on the permeability and dispersivity was investigated. Experimental results showed that the permeability of a sandy media depends on the biomass if the biomass is less that 0.4 mg of organic carbon/cm^3, and becomes independent of the biomass for higher values. Changes in permeability and dispersivity as a function of the biofilm thickness were modeled successfully using a modified cut-and-random-rejoin-type model.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB-89178594

PUBLICATION:

Baek, N. H., and Jaffe, P. R., 1988, The degradation of trichloroethylene in mixed methanogenic cultures: Journal of Environmental Quality, v. 18, October.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1315

TITLE: Selective Removal of Trace Organics Using Surface Grafted Polymers

PERFORMING ORGANIZATION: University of California at Los Angeles

PRINCIPAL INVESTIGATOR: Y. Cohen

START: September 1986

FINAL REPORT RECEIVED: November 1988

ABSTRACT:

The objectives of this project were to develop and evaluate polymeric resins for the selective removal of trace organics from contaminated water supplies and wastewater streams. Available polymeric adsorbents and novel polymer-silica resins were evaluated as potential adsorbents for the selective removal of organic contaminants aqueous systems. An adsorption data base was developed for the adsorption of trichloroethylene, chloroform and phenol, onto a variety of adsorption resins. The affinity of various resins for the adsorption of the above organics was evaluated based on the amount of adsorbed solute per available surface area. The possibility of removing organics from aqueous systems using hydrophilic polymeric resins was demonstrated, for the first time, for phenol adsorption. These latter resins were polymeric-silica matrix resins which were synthesized using a novel technique of graft polymerization. The results of the current study have shown that polymer-silica matrix resins can be potentially useful adsorption resins for the selective removal of organics.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-214480/AS

PUBLICATIONS:

Cohen, Y., 1988, The hydrodynamic thickness of macromolecules in steady shear flow: Macromolecules, v. 21, p. 494.

Cohen, Y., Chaimberg, M., and Parnas, R., in press, Surface-grafting polymerization of polyvinylpyrrolidone: Journal Applied Polymer Science.

Cohen, Y., Parnas, R., Chaimberg, M., and Taepaisitphongse, V., in press, Effect of surface chemistry on the adsorption of polyvinylpyrrolidone: Journal Colloid Interface Science.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1154

TITLE: Effects of Microtopography and Vegetation Cover Density on Infiltration and Runoff

PERFORMING ORGANIZATION: University of Washington

PRINCIPAL INVESTIGATORS: Thomas Dunne and Terrance W. Cundy

START: September 1985

FINAL REPORT RECEIVED: December 1988

ABSTRACT:

The research investigated the effects of vegetation and microtopography on infiltration and runoff through mathematical modeling and synthesis of fieldwork and previously published research. Two modeling approaches were used in the study. The first utilized a steady-state kinematic wave approach to model a corrugated microtopography where infiltration capacity and roughness both increase with elevation in response to the presence of vegetation. The second approach utilized the full two-dimensional, unsteady equations of open-channel flow.

The original hypothesis of a positive relationship between infiltration rate and rainfall rate is supported by the kinematic wave modeling results. The model reproduces field data well, and is simple and accurate enough to be incorporated into runoff predictions.

The two-dimensional model leads to important knowledge of hillslope runoff and erosion processes, reproducing the few available field measurements quite well. Simulations of hypothetical surfaces show that microtopography has a dominant effect on the depth, velocity and direction of flow. The effects of spatial variation in infiltration and surface roughness are secondary. The results of the research contribute to understanding overland flow in two ways.

First, for the purpose of hydrologic analysis and prediction, empirical observations of increasing infiltration rate with increasing rainfall rate have been explained from a process perspective. The role of vegetation and its association with high infiltration capacities and large surface roughness is shown to be important and is quantified. Second, the development of a two-dimensional model of overland flow has led to new insights into the process of overland flow on real hillslopes. The knowledge and prediction of overland flow fields is well beyond previous work. Furthermore, the results apply directly to the problem of surface erosion.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-178586

PUBLICATION:

Zhang, W., and T. W. Cundy, in press, Modeling of two-dimensional overland flow: Water Resources Research.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1288

TITLE: A Feasibility Study of the Privatization of Public Wastewater Treatment Works

PERFORMING ORGANIZATION: Auburn University

PRINCIPAL INVESTIGATORS: John Heilman and Gerald Johnson

START: September 1986

FINAL REPORT RECEIVED: January 1989

ABSTRACT:

A national feasibility assessment of capital-intensive privatization (CIP) of municipal wastewater treatment works (WTWs) was conducted. The initial WTW CIP deals, of which there were fewer than a dozen, were driven in part by Federal tax incentives created in 1981 and 1982. These deals involved private sector financing, design, construction, operation, and ownership of WTW facilities. Tax reform in 1986 removed most of the tax incentives, but the water industry remains interested in developing the CIP option. In the post-1986 era, one deal has been completed; others are in varying stages of development. Methods including case studies, mail and telephone surveys, document analysis, and aggregate data analysis were used to assess the legal, economic, political, and administrative feasibility of WTW CIP. The conclusion reached is that the WTW CIP option offers inherent efficiencies which are independent of tax incentives.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-155642/AS

PUBLICATIONS:

Heilman, J. G., 1986, Wastewater treatment in Alabama: local needs and plans for plant improvement: Center for Governmental Services Report. Interaction 17, December 10.

Johnson, G. W., and Heilman, J. G., 1987, Diffusion of innovation: process, coupling, and constraints on the adaptation and omplementation of privatization: Paper presented at American Political Science Association, September 1987, and submitted for publication, 1988.

Johnson, G. W., and Watson, D. J., 1985, Privatization fills the funding Gap: Public Works (March), p. 91-92.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1311

TITLE: Geostatistical Interpolation of Hydrostratigraphy at Ground-Water Contamination Sites

PERFORMING ORGANIZATION: University of California, Santa Cruz

PRINCIPAL INVESTIGATORS: Shirley T. Dreiss and Nicholas M. Johnson

START: September 1986

FINAL REPORT RECEIVED: January 1989

ABSTRACT:

In this report, the investigators illustrate the use of indicator geostatistics for interpreting complex alluvial stratigraphy from qualitative borehole logs. They describe locations of relatively high and low permeability regions by inferring relative permeability from borehole descriptions and assigning binary indicator values of either 1 or 0 to intervals in the borehole logs. The resulting indicator data is then used to compute experimental variograms and construct three-dimensional variogram models. The approach is applied to a ground-water contamination site in Santa Clara Valley, California. Computed indicator variograms are consistent with known stratigraphic features. In addition, they describe details in the spatial structure of the deposits that reflect differing depositional environments. Kriged indicator values represent probabilities that sediments at a specific location fall into one of the two indicator categories. The location of the 0.5 indicator contour is approximately the aquifer-aquitard boundary that might be constructed in a geologic cross-section. In addition, indicator kriging consistently weighs all the available data on the basis of a three-dimensional, anisotropic variogram model and provides an estimate of uncertainty in the hydrostratigraphic correlation.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-143507/AS

PUBLICATIONS:

Johnson, N. M., and Dreiss, S. J., 1986, Geostatistical characterization alluvial stratigraphy from borehole data at ground-water contamination sites: Geological Society of America Abstracts with Programs, v. 18, n. 6, p. 648. (Symposium on Scientific Advances in Geology and Hydrology from Studies of Contaminant Plumes, GSA Annual Meeting, San Antonio, Texas).

Johnson, N. M., and Dreiss, S. J., 1987, An indicator geostatistics approach to hydrostratigraphic interpretation: Trans. American Geophysical Union, v. 68, n. 16, p. 299.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1126

TITLE: Investigation of the Transport and Fate of Gasoline Hydrocarbon Pollution in Ground Water

PERFORMING ORGANIZATION: Orange County Water District

PRINCIPAL INVESTIGATORS: Harry Ridgeway, Perry McCarty, and Martin Reinhard

START: September 1985

FINAL REPORT RECEIVED: January 1989

ABSTRACT:

Ground-water and aquifer solids from a shallow, semi-perched zone of silty/sandy alluvial desposits contaminated by 20 to 30 thousand liters of regular, unleaded gasoline were analyzed. Gasoline migration and an enrichment of napthalene and p/m-xylene near the periphery of the plume were determined by gas chromatographic analyses. Gasoline-degrading bacteria from the site were sorted into 111 distinct subpopulations on a battery of 15 specific hydrocarbons representing the major chemical groups in the gasoline. Each of the 15 test hydrocarbons supported the growth of at least one bacterial isolate. Two hundred eighty seven isolates capable of gasoline degradation were sorted into 59 distinct bacterial subpopulations. The heterogeniety of the microbial community was demonstrated by a computer programmed analysis of whole cell protein banding patterns. The aerobic, gasoline-degrading bacteria in the ground water varied in number from one to several hundred colony forming units per milliliter and inversely with the hydrocarbon toulene. Exposure of the bacteria to gasoline vapors caused physiological injury, accelerated death and segregation of mutant, non-degrading strains. Metabolism of one or more specific hydrocarbons was required for the full microbicidal activity of the gasoline. Biotransformation and/or complete mineralization of selected aromatic gasoline constituents (e.g., toluene and p-xylene) was demonstrated under anerobic (denitrifying or methanogenic) conditions.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-151450/AS

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1284

TITLE: In-Situ Control of Ground-Water Contaminants of Microbiological Processes

PERFORMING ORGANIZATION: Montana State University

PRINCIPAL INVESTIGATORS: William G. Characklis, Al Cunningham, and Edward J. Bouwer

START: September 1986

FINAL REPORT RECEIVED: January 1989

ABSTRACT:

Processes governing biofilm accumulation in porous media flow are discussed along with their relationship to biotransformation of organic contaminants in ground water. The rates of biofilm accumulation and biotransformation are strongly influenced by transport characteristics including pore velocity distribution, dispersivity, molecular diffusivity, surface roughness and other variables which affect the delivery rate of substrate and nutrients to the growing cells. Transformation rates are further affected if biomass accumulation becomes so large as to alter porous media transport characteristics. Thus, the processes of subsurface mass transport, biotransformation, and biofilm accumulation are highly interrelated. This report demonstrates these interrelationships by discussing fundamental concepts and results from laboratory and field investigations related to analysis and mitigation of porous media biofouling and in-situ biodegration of organic ground-water contaminants.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-148464/AS

PUBLICATIONS:

Crawford, D. J., 1987, Hydraulic effects of biofilm accumulation in simulated porous media flow systems: Masters Thesis, Department of Civil and Agricultural Engineering, Montana State University.

Cunningham, A. B., Bouwer, E. J., and Characklis, W. G., in press, Biofilms on prorous media: textbook chapter in Biofilms, W. G. Characklis and K. C. Marshall, Editors.

Bouwer, E. J., 1987, Theoretical investigation of particle deposition in biofilm systems: Water Research, v. 21, no. 12, p. 1489-1498.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1150

TITLE: A Novel Two-Stage Three-Phase Fluidized Bed Bioreactor with Immobilized Living Cells for Wastewater Treatment Application

PERFORMING ORGANIZATION: Ohio State University

PRINCIPAL INVESTIGATOR: L. S. Fan

START: September 1985

FINAL REPORT RECEIVED: January 1989

ABSTRACT:

This research investigated the fundamentals and practical design and operation of a novel two-stage three-phase fluidized bed bioreactor for cost-effective wastewater treatment. Phenol biodegradation was selected as a model biodegradation system for this study. The fundamental studies included bubble wake structure and dynamics, solid mixing, gas-liquid mass transfer, biofilm characteristics, and biodegradation kinetics. Comprehensive mathematical models for steady state and dynamic phenol biodegradation in both draft tube and conventional three-phase fluidized bed bioreactors were developed and experimentally validated. These models provided guidelines for design, control and optimization of biodegradation processes in three-phase fluidized bed bioreactors. The knowledge of fundamental transport phenomena and the guidelines derived from the mathematical models developed in this study were incorporated in the design and operation of a novel two-stage three-phase fluidized bed bioreactor. The two-stage bioreactor was demonstrated to successfully integrate immobilization, biofilm development, biodegradation and biofilm control functions into one single unit with least human intervention. The performance of the two-stage bioreactor in terms of biodegradation rate per unit solid loading was shown to be superior to that of a one-stage three-phase fluidized bed bioreactor.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB 89178602

PUBLICATIONS:

Wisecarver, K. D., and Fan, L. S., 1989, Biological phenol degradation in a gas-liquid-solid fluidized bed reactor: Biotechnology and Bioengineering, v. 33, p. 1029-1038.

Tong, C. C., and Fan L. S., 1988, Concentration multiplicity in a draft tube fluidized-bed bioreactor involving two limiting substrates: Biotechnology and Bioengineering, v. 31, p. 24-34.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1286

TITLE: Removal and Selective Recovery of Heavy Metal Ions from Industrial Waste Waters

PERFORMING ORGANIZATION: New Mexico State University/New Mexico Water Resources Research Institute

PRINCIPAL INVESTIGATORS: Dennis W. Darnall and Jorge Gardea Torresday

START: September 1986

FINAL REPORT RECEIVED: March 1989

ABSTRACT:

The influence of hard-water components (calcium and magnesium ions) on metal ion binding to different algal biomasses was investigated. Concentrations as high as 10,000 ppm of calcium and magnesium ions were virtually without effect on the binding of copper, aluminum, gold, and mercury ions to harvested cells of Spirulina or Cyanidium. Slight inhibition of cadmium, nickel, and zinc ion binding was observed for both algal species.

Different algal-silica polymers showed good copper binding properties when exposed to an authentic copper-plating bath sample. However, various algal polymers exhibited substantial variations in performance under comparable conditions.

The algae, Spirulina and Cyanidium, were cultured under different nitrogen concentrations. Metal ion binding experiments with the resultant biomass indicated that the nitrogen concentration present during growth of Spirulina had no impact on its metal ion binding capacity. Conversely, the metal ion binding capactiy of Cyanidium was decreased in biomass grown at nitrogen levels below those found in the normal growth medium; however, growth medium nitrogen concentrations above normal may cause increased expression of high affinity gold binding sites. The copper binding capacity of Cyanidium biomass was found to increase, when cells were cultured in medium containing elevated levels of copper ion.

The mechansim of metal ion binding to algae was studied by modifying algal chemical functional groups. These modifications showed that carboxyl groups are primary binding sites. Amino and sulfhydryl groups also play a role in algal metal ion binding, but to a lesser extent.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-166763/AS

PUBLICATIONS:

Darnall, D. W., Greene, B., Henzel, M. T., Hosea, J. M., McPherson, R. A., Snedden, J., and Alexander, M. D., 1986, Selective recovery of gold and other metal ions from an algal biomass: Environmental Science and Technology., v. 20, p. 206-208.

Darnall, D. W., Greene, B., Hosea, M. T., McPherson, R. A., Henzl, M. T., Alexander, M. D., 1986, Recovery of heavy metals by immobilized algae, in Thompson, R., ed., Trace Metal Removal from Aqueous Solutions: London, The Royal Society of Chemistry, Burlington House.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1298

TITLE: The Light-Sensitized Decontamination of Ground-Water Hazardous Chemicals

PERFORMING ORGANIZATION: University of Illinois

PRINCIPAL INVESTIGATORS: Richard A. Larson, Martina B. Schlauch, David D. Ellis, Karen A. Marley, and Hui-Lin Ju

START: September 1986

FINAL REPORT RECEIVED: March 1989

ABSTRACT:

The use of sunlight, oxygen, and dissolved organic compounds active as "photosensitizers" (substances capable of absorbing sunlight and transforming it into chemically useful forms) is a promising treatment for contaminated waters. Light is absorbed by the sensitizing substance, raising it to a higher energy excited state. Reaction with the excited state substance converts molecular oxygen to a form much more reactive with dissolved compounds. Riboflavin (Vitamin B2), a naturally occurring compound and a known photosensitizer, was investigated for use in this process. A series of kinetic experiments explored its ability to photodegrade several aromatic compounds, phenols and anilines, that are related to some herbicides (such as carbaryl 1, 2, 4-D, alachlor, atrazine, and trifluralin) commonly found in polluted waters. It was found that riboflavin when added to solutions of phenols or anilines greatly accelerated the rate of their loss in the presence of light. The sensitized photolysis rates increased in the absence of oxygen, suggesting a mechanism involving direct energy or electron transfer between flavin excited states and acceptor molecules. In addition, it was found that some iron salts were highly significant promoters of photodestruction of the triazine herbicide, atrazine.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB 89178578

PUBLICATIONS:

Larson, R. A., Ellis, D. D., Ju, H. -L., and Marley, K. A., 1989, in press, Flavinsensitized photodecomposition of anilines and phenols: Environmental Toxicology and Chemistry.

Larson, R. A., Schlauch, M. B., Ellis, D. D., Marley, K. A., in press, Strategies for the photochemical treatment of contaminated waters, in Tedder, D. W., ed., Emerging Technologies for Hazardous Waste Treatment: American Chemical Society Symposium Series.

Schlauch, M. B., 1989, Sensitized photodecomposition of triazine herbicides: University of Illinois, Urbana., 80p.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1146

TITLE: Investigation of the Structural Features and Interactions of Aquatic Fulvic Acids

PERFORMING ORGANIZATION: University of North Texas

PRINCIPAL INVESTIGATOR: Farida Y. Saleh

START: September 1985

FINAL REPORT RECEIVED: April 1989

ABSTRACT:

Structural features and interactions of aquatic fulvic acids (FA) were investigated by combined chromatographic and spectroscopic techniques. Analytical and preparative reversed-phase liquid chromatography were used to separate constitutents of FA. Photodiode array, ultraviolet, and fluorescence detectors were used to monitor the high pressure liquid chromatography (HPLC) separation. Preparative FA fractions were subjected to ^{1}H and ^{13}C solid state nuclear magnetic resonance (NMR), fourier transform-infrared electron spin resonance (ESR), as well as other separation and derivatization techniques. Fluvic acid interactions with Cu^{2+} and tetrachlorobenzene isomers were investigated by ESR and HPLC and gas chromatography-mass spectrometry. A catalogue of the ultraviolet-visible scans of FA constituents was developed using reversed-phase (RP)-HPLC under different mobile phases and gradient programs. The overall results indicate that: (1) FA macromolecule consists of molecular complex which can be separated into three to six subunits; (2) each subunit may contain two or three structurally related compounds; (3) vanillic acid, conjugated ketones and phenols represent the backbone structures in FA; (4) the free radical in FA regulates the transformation of 1, 2, 4, 5 tetrachlorobenzenes in aqueous solution but does not influence its aqueous solubility; and (5) at least four binding sites in FA participate in complexation with Cu^{2+}. The first available sites are those participating in square planar complexes.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-193429/AS

PUBLICATIONS:

Saleh, F. Y., and Chang, D. Y., 1987, Retention behavior of Suwannee fulvic acid components in RP-HPLC: Science of the Total Environment 62, p. 67-74.

Saleh, F. Y., Theriot, L. J., Amani, S. K., and Inyoung, I., 1989, Electron spin resonance of Suwannee River fulvic and humic acids: In Humic Substances in the Suwannee River, Florida and Georgia: Interactions, Properties, and Proposed Structures: U.S. Geol. Open-File Report 87-557, p. 134-199.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1130

TITLE: Analysis of Soilwater Movement on a Sandy Hillslope

PERFORMING ORGANIZATION: New Mexico Water Resources Research Institute/
New Mexico Institute of Mining and Technology

PRINCIPAL INVESTIGATORS: Daniel B. Stephens and James T. McCord

START: September 1985

FINAL REPORT RECEIVED: April 1989

ABSTRACT:

Field experiments were conducted on a virtually unvegetated, thinly stratified sand dune near Socorro, New Mexico, to determine whether soil moisture movement had significant horizontal flow components. The site is in a semi-arid area where mean annual precipitation is about 20 cm. The site was instrumented with tensiometers and neutron probe access tubes to monitor soil water movement. These instruments show that near unit vertical hydraulic gradients occur and that moisture from infiltrated precipitation propagates deep into the sand, except near the dune crest. A bromide tracer buried at different locations beneath the dune slope was found by core sampling to have moved a significant distance downslope from the source. We infer that soil moisture does exhibit horizontal flow components, even though the hydrualic gradient is near vertical.

A series of numerical simulations was conducted to identify the most likely explanation for the observed field behavior. The principal phenomena considered were: (a) hysteresis in the moisture characteristic curves which prolongs the retention of infiltrated water in a zone sloping nearly parallel to the dune slope; and (b) anisotropy which is either constant at all saturations or which increases with decreasing saturation. A finite element flow and transport code, VAM2D, was modified to account for hysteresis and state-dependent anisotropy. Input hydraulic properties were derived from extensive field and laboratory characterization. The soil moisture characteristic curve was highly hysteretic but the soil was only slightly anisotropic at saturation. Nevertheless, the simulation of rainfall infiltration showed that the field behavior is mostly attributed to state-dependent anisotropy. This finding tends to support recent theories on anisotropy of unsaturated soil.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-182885/AS

PUBLICATIONS:

McCord, J. T., and Stephens, D. B., 1987, Lateral moisture flow beneath a sandy hillslope without an apparent impeding layer: Hydrological Processes, v. 1, p. 225-238.

McCord, J. T., and Stephens, D. B., 1987, Comment on "Effect of ground-water recharge on configuration of the water table beneath sand dunes" by T. C. Winter; Journal of Hydrology, v. 95, p. 365-367.

McCord, J. T., and Stephnes, D. B., 1988, Comment on "Effective and relative permeabilities of anisotropic porous media" by Bear, Braester, and Menier: Transport in Porous Media, v. 3, p. 207-210.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1296

TITLE: Computation of Three-Dimensional Advection-Dominated Solute Transport in Saturated Aquifers

PERFORMING ORGANIZATION: Vanderbilt University

PRINCIPAL INVESTIGATORS: A. D. Koussis, D. Syriopoulou, and G. Ramanujam

START: September 1986

FINAL REPORT RECEIVED: April 1989

ABSTRACT:

The objective of this project was been to deliver an accurate and efficient computational tool for three-dimensional ground-water solute transport with grid sized and resolution required for field applications that will enable geohydrologists to carry out routinely a credible analysis and prediction of ground-water contamination. Efficient methodologies were devised that acknowledge the nature of advection-dominated transport, and address the problem of transverse numerical diffusion caused by grid anisotropy. A suite of models was constructed suitable for simulating transport in a steady flow field. The final tests entailed simulation of the chloride plume observed under the Borden landfill in Ontario, Canada. The two-dimensional and three-dimensional simulation study can be quite different. This conclusion should be accepted as being site specific and somewhat impaired by the uncertainty of data on three-dimensional domain geometry, on source definition, and on concentration distribution.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-214472/AS

PUBLICATION:

Syriopoulou, D., and Koussis, A. D., 1988, Two-dimensional modeling of advection-dominated solute transport in ground water: Hydrosoft, v. 1, no. 2, April, p. 63-70.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1492

TITLE: Lifetime Studies and Optimization for AFT-Treated Electrodialysis Membranes

PERFORMING ORGANIZATION: Georgia Institute of Technology

PRINCIPAL INVESTIGATOR: Joel D. Shutt

START: September 1987

FINAL REPORT RECEIVED: May 1989

ABSTRACT:

This work was conducted to determine the effect of Anti-Fouling Technology (AFT) treatment of electrodialysis (ED) membranes on system performance and lifetime. This study has helped to evaluate some of the critical performance parameters which must be considered in the application of AFT to the ED process.

An experimental procedure was developed for coating membranes which were larger than any which had previously been coated using our apparatus.

Although the data for the lifetime studies were not fully conclusive, they indicated that the application of an oriented monomolecular layer of a fluorinated surfactant by the Langmuir-Blodgett process may prolong the operating life of electrodialysis membranes.

A designed experiment which was run in order to characterize the response of the system to changes in flow rate, concentration, foulant load, and the membrane coating showed that the coating appeared to lower the limiting current slightly. This is believed to be due to a lowering of the rate of ion transport across the boundary layer which is caused by the presence of the monolayer. The determination of the limiting current, however, was subject to differences in interpretation because the current-voltage characteristic was somewhat anomalous.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-193411/AS

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1137

TITLE: Binding of Xenobiotics to Humic Material in the Aquatic Environment

PERFORMING ORGANIZATION: The Pennsylvania State University

PRINCIPAL INVESTIGATOR: Jean-Marc Bollag

START: September 1985

FINALS REPORT RECEIVED: May 1989

ABSTRACT:

The research evaluates using immobilized enzymes, oxidoreductases and hydrolases to remove or detoxify phenolic and pesticidal compounds from the aquatic environment. Particularly, the research focuses on the binding of zenobiotics to humic substances through the activity of oxidoreductive enzymes. Experiments with bound chlorophenols indicated that release, especially microbial release, from humic material was limited and small amounts were mineralized by microorganisms.

Experiments indicate that immobilized enzyme can be used for detoxifying various various pollutants by enzyme-catalyzed polymerization or binding of phenolic and other xenobiotic compounts to humic substances.

A number of oxidoreductases and hydrolases were covalently linked to various types of soils and clays using 3-aminopropyltriethoxysilate (APTES) and glutaraldehyde as "coupling agents."

Most enzymatic activity was recovered for a phenoloxidase, namely a laccase. Incubation of this laccase with 2, 4-dichlorophenol caused the formation of oligomers, which are insoluble in aqueous solution and thus can be removed. The coupling of 2, 4-dichlorophenol to fulvic and humic acid could also be determined in the presence of other oxidoreductases, such as tyrosinase, peroxidase and a laccase of Rhizoctonia praticola.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-193379/AS

PUBLICATIONS:

Bollag, J. M., Shuttleworth, K. L., and Anderson, D. H., 1988, Laccase mediated detoxification of phenolic compounds: Applied and Environmental Microbiology, v. 54, p. 3086-3091.

Dec, J., and Bollag, J. M., 1988, Microbial release and degradation of catechol and chlorophenols bound to synthetic humic acid: Soil Science Society of America Journal, v. 52, p. 1366-1371.

Leonowicz, A., Sarkar, J. M., and Bollag, J. M., 1988, Improvement in stability of an immobilized fungal laccase: Applied Microbiology Biotechnology, v. 29, p. 129-135.

Sarkar, J. M., Malcolm, R. L., and Bollag, J. M., 1988, Enzymatic coupling of 2, 4-dichlorophenol to stream fulvic acid in the presence of oxidoreductases: Soil Science Society of America Journal, v. 53, p. 688-694.

Sarkar, J. M., and Bollag, J. M., 1987, Inhibitory effect of humic and fulvic acids on oxidoreductases as measured by the coupling of 2, 4-dichlorophenol to humic substances: Science of the Total Environment, v. 62, p. 367-377.

Ruggiero, P., Sarkar, J. M., and Bollag, J. M., 1989, Detoxification of 2, 4- dichlorophenol by a laccase immobilized on soil or clay: Soil Science, v. 147, no. 5.

Sarkar, J. M., Leonowicz, A., and Bollag, J. M., 1989, Immobilization of enzymes on clays and soils: Soil Biology and Biochemistry, v. 21, p. 223-30.

Bollag, J. M, in press, Decontamination of the environment through binding of pollutants to humic materials, In Glaser, J. A., ed., Chemical and biochemical detoxification of hazardous waste: Michigan, Lewis Publishers, Inc.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1318

TITLE: Stochastic Design of Wastewater Storage for Land Application

PERFORMING ORGANIZATIONS: The University of Texas at Austin and University of Cincinnati

PRINCIPAL INVESTIGATORS: K. A. Al-Omari, S. G. Buchberger, and D. R. Maidment

START: September 1986

FINAL REPORT RECEIVED: May 1989

ABSTRACT:

This report presents an application of a probabilistic design method, based on the theory of Markov diffusion processes, to estimate the reliability of a wastewater storage pond subject to random inflows and outflows. Reliability is defined as the steady-state probability that wastewater will not encroach on a designated freeboard zone. The design method involves sizing a wastewater storage facility to meet a prescribed reliability criterion. Sizing includes computing the pond surface area, embankment height and storage capactiy. The method is applied to a case study of the Hancock Farm near Lubbock, Texas, where slow rate irrigation has been used since 1982 to treat municipal wastewater.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-236269

PUBLICATIONS:

Buchberger, S. G., and Maidment, D. R., 1989, Diffusion approximation for equilibrium distribution of reservoir storage: Water Resources Research, v. 25, no. 7, p. 1643-1652.

Buchberger, S. G., and Maidment, D. R., 1989, Wastewater storage at land treatment sites, 1. Parallels with reservoir theory: Journal of Environmental Engineering, American Society of Civil Engineers, v. 115, no. 4, p. 689-703.

Buchberger, S. G., and Maidment, D. R., 1989, Wastewater storage at land treatment sites, 2. Storage performance functions: Journal of Environmental Engineering, American Society of Civil Engineers, v. 115, no. 4, p. 704-724.

Buchberger, S. G., and Maidment, D. R., 1988, A diffusion theory for stochastic storage analysis: Center for Research in Water Resources Report No. 224, University of Texas at Austin, p. 224.

Al-Omari, K. A., and Buchberger, S. G., 1989, Design of wastewater ponds based on stochastic storage analysis: Center for Research in Water Resources Report No. 193, p. 140.

Buchberger, S. G., and Maidment, D. R., 1986, Stochastic design of wastewater ponds, in Karamouz, M., et al., ed., Water Forum '86: World Water Issues in Evolution: American Society in Civil Engineers, v. 1, p. 435-472.

Buchberger, S. G., and Maidment, D. R., 1987, Stochastic design of wastewater ponds: Proceedings of ASCE Water Resources Planning and Management Division Specialty Conference, Kansas City.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1320

TITLE: Efficient and Equitable Solution of Indian Reserved Rights

PERFORMING ORGANIZATION: University of Arizona

PRINCIPAL INVESTIGATORS: William B. Lord and Thomas R. McGuire

START: September 1986

FINAL REPORT RECEIVED: June 1989

ABSTRACT:

The water rights claims of many Indian reservations in the West are now under adjudication. Frequently, the parties to these adjudications acknowledge that their interests may be better served through negotiated settlements, but they lack comprehensive means for determining mutually acceptable solutions to the conflicts. The research conducted under the title of "Efficient and Equitable Solution of Indian Reserved Rights" (Grant #14-08-0001-G1320) sought to 1) develop a conceptual basis for determining Indian water rights; 2) develop an analytical procedure to provide the information needed to resolve water rights conflicts; and 3) apply this analytical procedure to a test case involving the Gila River Basin in Arizona. The methodological core of the research is a set of linked models, encompassing historical, hydrologic, economic, psychological, and institutional elements of the conflict. Hydrologic, institutional, and economic analyses of conjunctive management of surface and ground-water supplies were facilitated by the use of MODSIM, a network optimization model.

Data from the model enabled the investigators to construct an impact matrix, defining the effect of each possible settlement option on the goals of the parties. The preferences of the parties were elicited through social judgment analysis. Twelve settlement options were defined on the basis of knowledge of other negotiated settlements, and a final option, representing possible outcomes should the negotiation process fail, was included in the analysis. The next step was to model the possible choices available the contending parties, utilizing an n-person cooperative game framework. This analysis indicated that a set of three settlement options dominated the adjudication option for all players. Each of these included the provision of imported water in lieu of water currently being used in the basin. It is anticipated that the results of this research will be developed as a book-length manuscript by the principal investigators and the research team.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-214498/AS

PUBLICATIONS:

Bazlen, W. R., 1989, Opportunities for resolving water allocation conflicts in the San Pedro River Basin of Arizona: Thesis submitted to the Faculty of the Department of the Hydrology and Water Resources in partial fulfillment of the requirements for the Degree of Master of Sciences with a major in Water Resources Administration, University of Arizona.

McGuire, T. R., 1989, Federal Indian Policy: A framework for evaluation: (Accepted by Human Organization for publication).

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1312

TITLE: Late Quaternary Paleohydrology of the Eastern Mojave River Drainage, Southern California: Quantitative Assessment of the Late Quaternary Hydrologic Cycle in Large Arid Watersheds

PERFORMING ORGANIZATION: New Mexico University

PRINCIPAL INVESTIGATORS: S. G. Wells, R. Y. Anderson, and L. D. McFadden

START: September 1986

FINAL REPORT RECEIVED: June 1989

ABSTRACT:

The objectives were to investigate historic climatic/hydrologic records and the latest Quaternary record from a climatically sensitive lake basin that provides a unique opportunity for determining the variability of climatic regions and hydrologic responses over the past 20,000 years within the Mojave River watershed, a large arid drainage basin in southern California. During the 20th century, several short-term lakes formed in the playas at the terminus of the Mojave River in response to precipitation/flood runoff thresholds in the Transverse Ranges, 200 km away from the terminal lakes. Modeling results of these conditions suggest that (1) significant increases in storm frequency and related moisture in the Transverse Ranges, and (2) an order of magnitude increase in frequency of lake-building flood events along the Mojave River are required to maintain lake levels observed in the geologic record in the terminal basins. Analyses of 13 cores from pluvial Lake Mojave reveal prolonged latest Pleistocene and short-duration Holocene lake events in response to the increased frequency of large-volume flood events. Data from these cores reveal strong millennia climatic oscillations, expressed as high and low lake stands, which developed in response to large scale, oceanic-atmospheric phenomenon during the latest Quaternary. Increased understanding of oceanic-atmospheric conditions producing these hydrologic events will enhance the future performance of the Mojave River hydrologic system.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-217582

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1473

TITLE: A Physically Based Network Model for Two- and Three-Phase Saturation-Capillary Pressure Relationships

PERFORMING ORGANIZATION: Massachusetts Institute of Technology

PRINCIPAL INVESTIGATORS: Michael A. Celia and Lin A. Ferrand

START: August 1987

FINAL REPORT RECEIVED: August 1989

ABSTRACT:

Computational network models may be used to simulate multiphase fluid displacement in porous media. In these models, the governing physical processes are described at the pore scale. The pore space is modeled as a regular lattice of pores and throats, and the governing equation is the Young-Laplace equation of capillary displacement. Computational models can be constructed to simulate a typical laboratory experiment used to obtain constitutive relationships such as the dependence of relative saturation on capillary pressure. Appropriate definitions of bulk properties allow saturation - capillary pressure ($S-P_C$) relations to be calculated from the network model results. These $S-P_C$ curves exhibit all of the important features of measured curves, including entry pressures, hysteresis, and residual saturations.

Results for two-phase models on both two- and three-dimensional lattices demonstrate the fundamental importance of dimensionality in multiphase problems: physically meaningful results can only be obtained in three dimensions, not in two dimensions. In addition, minimum size requirements for definition of a "respresentation elementary volume" (REV) can be determined for three-dimensional lattices. Computational experiments and comparison to actual laboratory measurements indicate significant sensitivity of the $S-P_C$ relation to pore-size distribution. Extension to three-phase displacement problems can be accomplished by judicious modification and enhancement of the two-phase model. These two- and three-phase models provide an important tool for studying many fundamental aspects of multiphase capillary displacement in porous media, including influences of wettability, material heterogeneities, and scale.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-236277

PUBLICATIONS:

Celia, M. A., and Ferrand, L. A., 1988, Parameter estimation for multiphase porous media systems: in Proc. ASCE National Conference on Hydraulic Engineering, Abt and Gessler (eds.), p. 558-563, ASCE, N.Y.

Ferrand, L. A., and Celia, M. A., 1989, Development of a three-dimensional network model for quasi-static immiscible displacement: in Proc. International Symposium on Contaminant Transport in Groundwater, Kobus and Kinzelbach (eds.), p. 397-403, A.A. Balkema, Rotterdam

Ferrand, L. A., Celia, M. A., and Soll, W. E., in press, Percolation-based models for pore-to-lab-scale calculations in multifluid porous media: to appear in Dynamics of Fluids in Hierarchical Porous Formations, Cushman (ed.), Academic Press, London.

Soll, W. E., Ferrand, L. A., and Celia, M. A., 1988, An enhanced percolation model for the capillary pressure - saturation relation: in Proc. VII International Conference on Computational Methods in Water Resources, Celia et al. (eds.), 165-170, Elsevier, N.Y.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1293

TITLE: The Effects of Nutrients and Pesticides Applied to Turf on the Quality of Runoff and Percolating Water

PERFORMING ORGANIZATION: The Pennsylvania State University

PRINCIPAL INVESTIGATORS: Thomas L. Watschke and Ralph O. Mumma

START: September 1986

FINAL REPORT RECEIVED: September 1989

ABSTRACT:

The objective of this investigation was to determine the effect that nutrients and pesticides applied to lawn-type turf had on the quality of runoff and leachate. The results indicate that dense, high quality turfgrass stands, regardless of establishment method, affect the overland flow process to such a degree that runoff is insignificant. The ability of this type of vegetative community to allow water to infiltrate and promote the metabolism of solutes suggests that it might even possess the ability to be used as a water-quality treatment medium. Levels of management required to produce the turf quality necessary for positive water-quality impacts have not been determined. It is assumed that many poor quality turfgrass areas are not recipients of sound professional management. While these sites may not exhibit the infiltration capacity of high quality turf, nutrients and pesticides are also much less likely to have been used on them. Finally, much of the highly managed turfgrass in the United States is maintained in regions of varying degress of urbanization. Considering the magnitude of runoff contributed by impervious surfaces and the fact that treated turfgrass acres in those watersheds constitute only a portion of the previous fraction of the landscape, dilution of any low-level "spikes" of nutrients and/or pesticides would certainly occur. Acceptable background levels of these materials in surface water have not been determined. However, it is likely that their concentrations in storm water and impact on receiving bodies of water would be considerably less than other urban pollutants not associated with well-managed turfgrass areas.

OBTAINABLE FROM: National Technical Information Services
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-236756/AS

PUBLICATIONS:

Watschke, T. L., 1989, Is pesticide runoff from turf increasing?: American Lawn Applicator, July.

Watschke, T. L., Hamilton, G., and Harrison, S., 1988, Runoff from turf as effected by establishment method: NYSTA Bulletin, v. 932, p. 1286-1287.

Harrison, S., Watschke, T. L., and Hamilton, G., 1988, Turfgrass runoff Update: American Sod Produces Association, Turf News, p. 10-12.

Watschke, T. L., Harrison, S., and Hamilton, G., 1988, Movement of nutrients and pesticides in runoff from turf slopes: Agronomy Abstracts, p. 157.

Watschke, T. L., Harrsion S., and Hamilton, G., 1989, Fertilizers, pesticides, lawn care and water quality: Proc. 59th Michigan Turfgrass Conference, v. 18, p. 113-114.

Watschke, T. L., Harrison, S., and Hamilton, G., 1989, Does fertilizer/ pesticide use on a golf course put water resources in peril?: U.S. Geol. Survey Green Section Record 27:5-8.

Watschke, T. L., Hamilton, G., and Harrison, S., 1988, Runoff from turf as affected by establishment method: Keynoter, v. 16, p. 1-2.

Harrison, Scott A., 1989, Effects of turfgrass establishment method and management on the quantity and nutrients and pesticide content of runoff and leachate: M.S. Thesis.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1304

TITLE: Soil Phase Photodegradation of Toxic Organics at Contaminated Disposal Sites for Soil Renovation and Groundwater Quality Protection

PERFORMING ORGANIZATION: Utah State University

PRINCIPAL INVESTIGATORS: W. Moore, R. R. Dupont, and J. E. McLean

START: September 1986

FINAL REPORT RECEIVED: September 1989

ABSTRACT:

Accurate assessment of the potential for contaminated soil remediation requires detailed knowledge of the fate of waste constituents within the soil environment. For many non-biodegradable organics compounds, photochemical degradation may provide a potential pathway for the removal of such compounds from soil surfaces. A study was conducted to evaluate the rate of photodegradation of 10 hazardous organic compounds from 3 soils, (silica gel), and 4 soil minerals (kaolinite, montmorillonite, illite, and calcite) under conditions of controlled irradiation. In addition, the effect of six amendment treatments (methylene blue, riboflavin, hydrogen peroxide, diethylamine, peat moss, and silica gel) on the rates of compound loss was also investigated. Soil and mineral samples were spiked with various combinations of m-cresol, quinoline, biphenyl, dibenzo[a]furan, fluorene, pentachlorophenol, phenanthrene, anthracene, 9H-carbazole and pyrene at either 500 or 1000 mg/kg initial soil concentration of each chemical. Amendments were applied to the soils and minerals and duplicate samples were irradiated in petri dishes under ultraviolet or visible light while spike controls were incubated in the dark. Linear regression of soil/mineral contaminant concentration data showed that first order kinetic modeling best described the degradation process. Significant loss of anthracene occurred on all surfaces tested although the rate of loss varied with surface type and, for some surfaces, with the spiking solution concentration and chemical mixtures. Anthracene loss from silica gel was the most rapid of all reactions observed. Skumpah soil, a light colored alkaline soil, yielded the greatest reduction in contaminant concentrations found in the soil studies. Calicum kaolinite displayed the most rapid kinetics of the mineral surfaces tested. Loss of the other test compounds was observed from only some of the surfaces investigated. Anthraquinone and fluorenone were identified as the major degradation products of the photoreaction of anthracene and fluorene. Under the conditions of this study, soil and mineral type, as well as surface renewal via mixing, were found to have more effect on degradation rates than any of the amendments that were tested.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB89-237267

PUBLICATIONS:

Dupont, R. R., Moore, W. M., and McLean, J. E., 1987, Preliminary laboratory evaluation of soil photodegradation of toxic organics: Third Conference on Current Concerns on Toxicity. San Francisco, California. November 17.

Hoff, R. H., Dupont, R. R., Moore, W. M., and McLean, J. E., 1988, Evaluation of the use of solar irradiation for the decontamination of soil residues: 81st Annual Meeting of the Air Pollution Control Association, Dallas, Texas. June 20-24. Preprint #88-6A.6.

Hoff, R. H., 1988, Soil phase photolysis of a simulated creosote waste: Report submitted in partial fulfillment of the requirements of the degree of Master of Science in Civil and Environmental Engineering. Utah State University, Logan, Utah.

Guimarin, E., 1988, Solar induced photodegradation of toxic organic compounds on a soil surface: Presented at Scholar's Day, Utah State University, Logan, Utah.

Dupont, R. R., Hoff, R. H., Moore, W. M., and McLean, J. E., 1989, Solar irradiation for the decontamination soils: Accepted for publication, Journal of the Air and Waste Management Association (formly Air Pollution Control Association).

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1297

TITLE: Optimal Real-Time Forecasting and Control of Reservoir Hydrosystems Using Remote and On-Site Sensors

PERFORMING ORGANIZATION: University of Iowa

PRINCIPAL INVESTIGATORS: Konstantine P. Georgakakos and Aris P. Georgakakos

START: September 1986

FINAL REPORT RECEIVED: September 1989

ABSTRACT:

Fulfillment of the objectives of reservoir systems depends critically upon the successful management of the naturally uncertain river flows. The reservoir-system control study is viewed as a two-step process: first, a valid model is developed that utilizes all available hydrometeorological data and reproduces the system's hydrometeorological response, reliably; second, an efficient optimization algorithm (controller) is designed to guide the model - and thereby the actual system - in successfully meeting its operational objectives. Reservoir-system management is viewed as a combined effort drawing on hydrologic as well as on operations research advances.

The key components of the hydrometeorlogical model proposed for the simulation of the reservoir-system response are: a physically-based two-dimensional rainfall prediction model; a soil moisture accounting model; channel routing models suitable for application to headwater catchments and to flood plains; and a state estimator that utilizes, in real time, all available hydrometeorological data and produces (a) updates of the model states, and (b) estimates of prediction uncertainty. The key components of the reservoir control scheme proposed are: the extended linear quadratic Gaussian (ELQG) control algorithm for the optimal operation of multiobjective reservoirs with (a) the ability to handle non-Gaussian reservoir input, and (b) an enhanced barrier-function method to efficiently handle reliability storage constraints; and a stochastic control method for the real-time operation of control levels.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-109356 Volumn I
PB90-109364 Volumn II

PUBLICATIONS:

Georgakakos, A. P., 1989, Extended linear quadratic gaussian (ELQG) control: further extensions: Water Resources Research, v. 25, n. 2, p. 191-201.

Georgakakos, A. P., 1989, in press, The value of forecasting in reservoir control: Water Resources Bulletin.

Georgakakos, A. P., Baltas, E., and Georgakakos, K. P., 1989, A new state-space model for river routing: under review, Water Resources Research.

Georgakakos, A. P., 1989, A two-level control method for hydropower scheduling: under review, Water Resources Research.

Georgakakos, K. P., and Brazil, L. E., 1987, Real-time flood and flash-flood forecasting using hydrometeorological models and modern estimation theory techniques, in Berga, L., and Dolz, J., eds., Flood Prediction and Warning Systems: Barcelona, Spain, Colegio de Ingenieros de Caminos Canales y Puertos, p. 184-227.

Shen, H., 1989, Spatially-lumped precipitation prediction models for real-time hydrology: M.S. Thesis, Department of Civil and Environmental Engineering, The University of Iowa, Iowa City, Iowa, 107 p.

Lee, T. H., and Georgakakos, K. P., 1989, A two-dimensional stochastic-dynamical quantitative precipitation forecasting model: Journal of Geophysical Research - Atmospheres. (Accepted for publication).

Lee, T. H., 1989, Stochastic-dynamical quantitative precipitation forecasting in the mesoscale: Ph.D. Thesis, Department of Civil and Environmental Engineering, The University of Iowa, Iowa City, Iowa.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1290

TITLE: Reductive Dehalogenation and Biooxidation of Chlorinated Ethenes and Methanes by Acetoclastic Methanogens

PERFORMING ORGANIZATION: Michigan State University

PRINCIPAL INVESTIGATOR: Stephen A. Boyd

START: August 1, 1986

FINAL REPORT RECEIVED: September 1989

ABSTRACT:

The ability of pure cultures of Methanosarcina to dechlorinate tetrachloroethene (PCE), tetrachloromethane (CT) and bromoform (BF) were established. The dechlorinating bacterium DCB-1 was also shown to dechlorinate PCE. The methanogenic bacteria dechlorinate by a mechanism that is tightly linked to the process of methanogenesis. Over a wide range of primary substrate concentrations (methanol), the CH_4 - normalized rate of dechlorination remained constant. This rate was much greater (10X) however for CT as compared to PCE thus showing the dechlorination of chloromethanes to be more facile than chloroethenes. The metabolism of ^{14}C-CT by Methanosarcina did not produce $^{14}CH_4$ but $^{14}CO_2$ was detected showing that biooxidation was occurring. These results may imply that the activity of acetoclastic methanogens may be ecologically significant in anaerobic habitats contaminated with haloaliphatic compounds. The combined activities of dechlorination, methanogens and methylotrophic bacteria may be useful in the bioremediation of water and aquifer materials contaminated with chlorinated solvents.

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PUBLICATIONS:

Fathepure, B. Z., Nengu, J. P., and Boyd, S. A., 1987, Anaerobic bacteria that dechlorinate perchloroethene: Applied and Environmental Microbiology, v. 53, p. 2671-2674.

Fathepure, B. Z. and Boyd, S. A., 1988, Reductive dechlorination of perchloroethene and role of methanogens: FEMS Microbiology Letters, v. 49, p. 149-156.

Fathepure, B. Z. and Boyd, S. A., 1988, Dependence of tetrachloroethylene dechlorination on methanogenic substrate consumption by methanosarcina sp strain DCM: Applied and Environmental Microbiololgy, v. 54, p. 2976-2980.