WATER RESOURCES RESEARCH GRANT PROGRAM PROJECT DESCRIPTIONS, FISCAL YEAR 1987

U.S. GEOLOGICAL SURVEY
Open-File Report 88—179

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By Office of External Research
Water Resources Division
U.S. Geological Survey

U.S. GEOLOGICAL SURVEY
Open-File Report 88—179

Reston, Virginia
1987

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

For additional information write to:

Chief, Office of External Research
U.S. Geological Survey
Water Resources Division
424 National Center
Reston, Virginia 22092

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WATER RESOURCES RESEARCH GRANT PROGRAM
PROJECT DESCRIPTIONS, FISCAL YEAR 1987

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ABSTRACT

This report contains information on the 34 new projects funded by the United States Geological Survey's Water Resources Research Grant Program in fiscal year 1987 and on 3 projects completed during the year. For the new projects, the report gives the grant number; project title; performing organization; principal investigator(s); 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 34 projects include 12 in the area of ground-water quality problems, 12 in the science and technology of water-quality management, 1 in climate variability and the hydrologic cycle, 4 in institutional change in water-resources management, and 5 in surface-water management.

For the three completed projects, the report furnishes 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 copy of the final report.

The report 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 resarch 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. These projects are described in the U.S. Geological Survey Open-File Reports 85-687 and 86-548 respectively.

In FY 1987, 273 proposals requesting $30.8 million of Federal funding ($31.6 million of non-Federal funding) were submitted in response to U.S. Geological Survey Announcement No. 7127 issued on November 3, 1986. Of this number, 34 were selected for funding with the $4.381 million appropriation (Table 1). As in previous years, proposals from academic institutions dominated the competition (Table 2) for grant funds.

Section I of the report presents summaries of 34 proposals selected for funding. Section II presents summaries of the three projects completed during FY 1987.

Table 1.--Proposals and awards by research interest area, fiscal year 1987

Proposals

Interest Area	No.	Federal ($) Funds	Non-Federal Funds($)	Total Funds($)
Ground-water quality problems	77	8,216,269	8,470,122	16,686,391
Science and technology of water-quality management	99	12,596,891	12,855,564	25,452,455
Climate variability and the hydrologic cycle	20	1,847,351	1,870,420	3,717,771
Institutional change in water-resources management	36	3,581,113	3,619,944	7,201,057
Surface-water management	28	3,014,099	3,116,494	6,130,593
Other	13	1,548,864	1,656,851	3,205,715
Totals	273	30,804,587	31,589,395	62,393,982

Awards

Interest Area	No.	Federal($) Funds	Non-Federal Funds($)	Total Funds($)
Ground-water quality problems	12	1,384,649	1,452,700	2,837,349
Science and technology of water-quality management	12	1,661,311	1,713,147	3,374,458
Climate variability and the hydrologic cycle	1	166,000	166,000	332,000
Institutional change in water-resources management	4	528,789	551,463	1,080,252
Surface-water management	5	620,359	637,069	1,257,428
Other	0	0	0	0
Totals	34	4,361,108	4,520,379	8,881,487

Table 2.--Proposals and awards by organization, fiscal year 1987

Proposals

Organization	No.	Federal($)	Non-Federal Funds($)	Total Funds($)
Academic institutions	249	28,110,532	28,650,369	56,760,901
Non-Federal government	10	1,204,853	1,434,526	2,639,379
Industry	14	1,489,202	1,504,500	2,993,702
Total	273	30,804,587	31,589,395	62,393,982

Awards

Organization	No.	Federal($)	Non-Federal Funds($)	Total Funds($)
Academic institutions	33	4,289,652	4,435,929	8,725,581
Non-Federal government	0	0	0	0
Industry	1	71,456	84,450	155,906
Total	34	4,361,108	4,520,379	8,881,487

SECTION 1

PROJECT SUMMARIES

FISCAL YEAR 1987 GRANTS

GROUND-WATER QUALITY PROBLEMS

PROJECT INFORMATION

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 INVESTIGATOR: Michael A. Celia

DURATION: August 1987 to April 1989

DESCRIPTION

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

Hydrocarbon contaminants commonly enter the subsurface and remain in the soil as a separate phase, (for example, water, gas, soil, and undissolved hydrocarbon are separate phases) acting as a source of pollution for ground water. Analysis of the resulting two- or three-phase system is limited by a lack of information on the specific properties of the materials involved.

2. Contribution to Problem Solution.

Successful execution of this project could lead to techniques for prediction, through theoretical means, of fluid behavior in two- and three-phase ground-water contamination situations.

3. Objectives.

The objectives of this research are to:

(a) Develop a general three-dimensional mathematical model for two-phase, quasi-static displacement in unconsolidated porous media.

(b) Validate the model by comparison to experimental data.

(c) Extend the network model to three-phase quasi-static displacement in unconsolidated porous media.

4. Approach.

A mathematical model will be developed for predicting the important relations between fluid pressures and saturations in a two-phase system. The model will take into account the hysteresis between drainage and imbibition curves and the existence of residual saturations. The model will be calibrated for a single pair of fluids in an unconsolidated sand medium, and saturation-capillary pressure relations predicted by the calibrated model for other fluid pairs will then be compared to experimental data for these fluids.

The algorithm for the two-phase model will be modified to handle three fluids, and the model will be compared to experimental saturation-capillary pressure data for three fluids in an unconsolidated sand.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1477
TITLE:	Characterization of Fracture Geometry Utilizing Particulate Tracers and Borehole Temperature
PERFORMING ORGANIZATION:	University of Notre Dame
PRINCIPAL INVESTIGATOR:	Stephen E. Silliman
DURATION:	September 1987 to September 1990

DESCRIPTION

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

Three current water-resource problem areas of interest are hazardous waste isolation, nuclear waste isolation, and recovery of geothermal resources. Each of these areas involves simulation of flows in fractured rock to predict expected changes due to man's influence. Proper prediction of the reaction of natural, fractured rock to new hydrologic stresses is dependent on the understanding of the mechanisms controlling flow and transport in these media.

This project will attempt development of a series of field techniques that will provide the data necessary to estimate parameters required by the discrete fracture models for simulation of flow through fractured rock.

2. Contribution to Problem Solution.

Two general concepts have been accepted in the simulation of transport within fractured rocks. These are the continuum and the discrete fracture theories. The continuum concept represents the rock mass as a continuous unit through which water can flow with equal resistance at all locations. The discrete fracture theory considers the rock mass as a series of discrete, intersecting flow zones (fractures) separated by continuous regions of low permeability. Although field techniques are available for deriving appropriate parameters for continuum models, parameters required for the discrete fracture models cannot currently be measured in the field.

Difficulties in applying discrete fracture models have centered on determination of input parameters, such as fracture interconnection, fracture aperture, and fracture channeling. Although these parameters can be analyzed at exposed surfaces of the rock (for example, well bores or outcrops), surface expressions rarely give reliable estimates of parameters within the flow zone of interest. In particular, the techniques to be developed on this project are designed to provide statistical descriptions of fracture interconnectivity and fracture aperture. These techniques will provide the research and the consulting communities with new tools for predicting transport within fractured rocks.

3. Objectives.

A. Expand on a technique previously developed by the principal investigator by which changes in temperatures of the the water in the borehole during pumping (or injection) are used to define fracture interconnections. This technique will be applied to both pumping from open holes and pumping from isolated fractures. The change in water temperature is due to natural variations in ground-water temperature, not to an induced heat pulse.

B. Develop a combined field technique and stochastic theory whereby the observed movement of micro-particulates through fractures leads to characterization of the distribution of apertures within the fractures. It is anticipated that the statistical information obtained will be in the form of the first and and second moments of the aperture distribution.

C. Develop a theoretical model with which to use the variation in calculated mass recovery obtained from chemical tracer tests conducted in fracture networks to provide a characterization of channeling within fractures.

D. Develop sensitivity analyses on all fracture parameters characterized by the above techniques.

4. Approach.

In this work, a series of field techniques designed to provide information required for simulation of flow through fractured rock will be studied. First, response of borehole temperature to local stresses in the flow field (for example, pumping or injection) will be used to analyze fracture interconnectivity. Second, transport patterns of micro-particulates within fracture networks will be used as a means of interpreting fracture aperture distributions. Finally, through recent theoretical efforts, it has been shown that the calculated dispersivity and mass recovery obtained from a field chemical tracer test may vary with direction of measurement. This concept will be applied to fractured media as a means of analyzing channeling of fluids within fractures.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1478

TITLE: Sampling Strategies for Hydrological Properties and Chemical Constitutents in the Upper Vadose Zone

PERFORMING ORGANIZATION: The University of Arizona

PRINCIPAL INVESTIGATOR: A. W. Warrick

DURATION: September 1987 to August 1990

DESCRIPTION

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

Sampling strategies are needed to determine efficiently the spatial distribution of chemical constituents in pollutant-contaminated soil systems. This project proposes to sample the upper vadose zone in a soil, which is the recipient of large quantities of pollutants resulting from waste water, as well as those used in normal agricultural practices. The approach is to apply alternative optimal techniques for extrapolation of measured data. The techniques to be tested include geostatistical and nonparametric regression, as well as the use of surrogate measurements.

2. Contribution to Problem Solution.

Efficient sampling of the top 1 or 2 meters of the soil profile will be achieved by (a) application of geostatistics to infer pollutant and soil parameter values based on regionalized functions, and (b) identification of a surrogate property or variable that is easy to quantify and useful for adding information on the primary property or variable of interest.

3. Objectives.

The objectives of the research are to:

a. Compare optimum interpolation schemes for determining transport parameters and chemical constituents of the upper vadose zone.

b. Test transferability of geostatistical parameters from measured to similar unmeasured fields.

c. Test bulking strategies for reducing tests necessary to characterize mean soil properties at test sites.

d. Test reliability of hydraulic properties calculated from minimal information as relevant to soil water and chemical transport.

4. Approach.

Soil properties have considerable influence in the design of disposal areas as well as characterization of general non-point sources. Field soil samples will be collected from an active irrigation site. Sample collection will be limited to the upper vadose or treatment zone (0-1.5 meters) to maximize sample numbers for a modest budget outlay. All phases of the sampling, analyses, and numerics will be performed by a single group.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1484

TITLE: Investigation of Multi-Component Sorption and Desorption Rates in Saturated Ground-Water Systems

PERFORMING ORGANIZATION: North Carolina State University

PRINCIPAL INVESTIGATOR: Cass Miller

DURATION: August 1987 to July 1990

DESCRIPTION

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

Contamination of the ground-water resources of the United States by a variety of organic pollutants has become extensive, and cleanup of such contamination is a high national priority. Effective and economical response to the demand for mitigation of this problem requires a thorough understanding of contaminant fate and transport in ground waters. One of the most important processes operative in this situation is the sorption-desorption process in which contaminants move between the water phase and the soil phase. An accurate description of this process is a requisite for understanding and controlling pollutant movement in the subsurface environment.

2. Contribution to Problem Solution.

This project addresses the need for improved understanding of the sorption-desorption of multicomponent, hydrophobic, organic pollutants in aquifers where the soil has a low carbon content.

3. Objectives.

The overall objective of this project is to determine the influence of sorption-desorption rates and equilibrium on the movement of multicomponent, hydrophobic, organic pollutants in saturated ground-water systems. This overall objective can be divided into subobjectives:

(1) Determine the equilibrium and rate of sorption-desorption for single, binary, and multicomponent, hydrophobic, organic solutes to aquifer sands.

(2) Determine the relation between sorption-desorption rates and equilibria for a variety of solute-aquifer sand systems.

(3) Evaluate the significance of the sorption-desorption rates determined as a function of contaminant source.

(4) Evaluate the significance of sorption-desorption rates for typical heterogeneous aquifer conditions.

4. Approach

The approach to meeting the objectives will include both new experimental methodologies and mathematical modeling of the experimental data. The experimental methods to be used include computer-controlled, real-time, data acquisition and storage by using fiber-optic spectroscopy methods for the determination of fluid-phase solute concentrations. Variants of this basic methodology are applied to three different reactor configurations used to study the sorption-desorption process. Mathematical modeling and statistical certainty analysis will be applied to all data collected to aid the interpretation of the experimental results. The modeling methods will also be used to extend and interpret the experimental findings with respect to the source function and aquifer heterogeneity.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1485

TITLE: Drainage Effects on Salinization, Organic Matter, and Selenium in Wetland Soils

PERFORMING ORGANIZATION: North Dakota State University

PRINCIPAL INVESTIGATOR: J. L. Richardson

DURATION: August 1987 to July 1990

DESCRIPTION

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

North Dakota's numerous prairie-pothole wetlands are an important hydrologic resource that directly influences the quantity and quality of much of the State's surficial ground water and surface water. The hydrologic and biologic importance of these wetlands often is balanced against their agricultural value after drainage. Attempts have been made to integrate wetlands into local and regional land-use plans by considering specific hydrologic, biologic, and geologic characteristics that influence potential use; however, lack of information on the complex hydrology and general morphology have complicated this evaluation in the past. Additionally, these semipermanent wetlands may act as sinks for elements of potential toxicity, notably selenium. Selenium accumulated in a wetland has a high potential to be mobilized on drainage of a wetland. This research will investigate the chemical and pedologic changes attendant upon drainage of these wetlands in North Dakota.

2. Contribution to Problem Solution.

The research will assess the consequences of wetland drainage on soil and water quality, and could greatly increase our knowledge of possible environmental impacts, resulting in cost-saving agricultural practices.

3. Objectives.

The objectives of the research proposed herein are to investigate and evaluate changes in soil and ground-water salinity, soil organic matter relations, and selenium concentration, and mobility that occur in natural and drained flowthrough (semipermanent) wetlands in North Dakota, and to determine the environmental hazard, if any, of each.

4. Approach.

The approach used will be to compare existing, previously investigated wetland systems in typical glacial terranes with drained wetlands in the same terranes, using standard geochemical, pedological, and mineralogical techniques. The comparisons will be made for wetlands in two distinct geological settings: (1) shallow till areas overlying marine shales that are known to be excessively sodic and contain high selenium; and (2) outwash areas.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1486
TITLE:	Managing Ground-Water Pollution from Agriculture Related Resources: An Economic Analysis
PERFORMING ORGANIZATION:	Oregon State University
PRINCIPAL INVESTIGATOR:	Gregory Perry
DURATION:	September 1987 to August 1989

DESCRIPTION

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

Ground-water pollution is widely regarded as one of the major environmental policy problems for the 1980's and 1990's. Ground-water pollution related to agriculture, specifically nitrate pollution, is a serious problem in many parts of the United States. More intensive management of water and fertilizer resources, coupled with government regulations on use of these resources, may be necessary to reduce ground-water pollution in these areas. Although health benefits from reductions in nitrates may be substantial, changes in production practices and the imposition of regulations represent increased costs to farmers in the short run.

2. Contribution to Problem Solution.

Empirical results from application of the methodology to be developed in this project will suggest both the technical feasibility of changes in management practices to reduce ground-water pollution and the associated costs of these changes. The cost information may also be used to determine minimum cost strategies of meeting ground-water quality standards.

3. Objectives.

The objectives of the project are two-fold: (1) to develop a methodology for analyzing the economic impacts of reducing agriculture-related ground-water pollution; and (2) to apply the methodology to an area currently experiencing nitrate pollution in ground water.

4. Approach.

The analysis will require development of farm decision, irrigation scheduling, and ground-water models. These will be linked together in one analytical package so that, in combination, optimal management strategies can be identified that could reduce pollution levels in the Columbia Basin area of Oregon.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1489

TITLE: Compatibility of Physically-Based and Linear System Solute Transport Modeling Approaches and Their Conjunctive Application

PERFORMING ORGANIZATION: University of Hawaii

PRINCIPAL INVESTIGATOR: K. Loague

DURATION: August 1987 to August 1990

DESCRIPTION

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

Assessment of potential ground-water contamination by toxic wastes applied to soils requires a thorough understanding of technical and economical consequences of such contamination. Any mathematical model used for assessment needs to be able to simulate the magnitude and time of occurrence for residual chemicals entering the underlying ground-water body. Conjunctive application of a physically-based approach and a linear system approach will be investigated to to improve existing techniques of solute transport modeling.

2. Contribution to Problem Solution.

Conventional transport models, following a physically-based approach, have some inherent problems in their application. These are due mainly to difficulties in parameter identification and to scale effects within heterogeneous soils. In a linear system approach the solute distribution in the soil can be calculated by a simple convolution operation of waste input and the impulse response function, thus avoiding some of the above problems.

3. Objectives.

a. To establish the compatibility of two modeling approaches by studying their underlying theories, and by evaluating their respective performances.

b. To investigate possible ways hydrodynamic and reaction mechanisms can be implicitly included in the impulse response function of a linear system model.

c. To develop techniques that allow the identification of parameter values of a physically-based model by the conjunctive use of a linear system model.

4. Approach.

This research is divided into two major phases. In the development phase, two solute transport modeling approaches will be evaluated with synthetically generated data. The demonstration phase will focus upon the utility of these modeling techniques in the Hawaiian hydrogeologic environment.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1490
TITLE:	Remote Determination of Soil Moisture and Evapotranspiration from Thermal Infrared Measurements: Detection of a Drying Threshold
PERFORMING ORGANIZATION:	Pennsylvania State University
PRINCIPAL INVESTIGATORS:	T. Carlson and J. Russo
DURATION:	September 1987 to August 1990

DESCRIPTION

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

The principal water-related problem addressed in this study is the lack of accurate measurements of soil moisture and the surface energy flux on a large scale for development of climate models and forecasts of crops productivity. Our approach is to establish soil surface temperature/moisture content/ evapotranspiration relations in a model through use of satellite infrared measurements of surface temperature.

2. Contribution to Problem Solution.

The research will contribute to more accurately sensing the soil moisture and evapotranspiration using remote temperature measurements, particularly those from satellites and particularly in regions subject to water stress.

3. Objectives.

The objectives of this proposal are to use available measurements, both in-situ and remote, to improve the techniques of remote sensing of soil moisture and also to improve evapotranspiration parameterizations in atmospheric prediction models, including a better method for specifying the initial soil water content.

4. Approach.

The approach is to use the model (in conjunction with measurements) as a tool for finding the correct functional relations and coefficients relating soil moisture to evapotranspiration, given a satellite-derived surface temperature measurement.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1491
TITLE:	Prediction of Ground-Water Flow and Mass Transport Using Linear and Nonlinear Estimation Methods.
PERFORMING ORGANIZATION:	Stanford University
PRINCIPAL INVESTIGATOR:	Peter Kitanidis
DURATION:	August 1987 to July 1989

DESCRIPTION

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

Predictions of ground-water flow and mass transport in geologic formations involve considerable uncertainty because of aquifer heterogeneity and scarcity of measurements. This research will develop methods to calculate, through the flow and mass transport equations, the probabilities of various events based on available information.

2. Contribution to Problem Solution.

The research will advance the field of statistical modeling of ground-water systems, improve the understanding of how heterogeneity affects flow and mass transport, and determine the accuracy and efficiency of existing and proposed methodologies.

3. Objectives.

The objective of the research is to develop methods for solution of the following problem: "Given measurements of hydrogeologic variables at given locations and times, pertinent flow and mass transport equations, and other prior information, predict the values of hydrogeologic variables at selected locations and places."

4. Approach.

The research will concentrate on two important problems: time-variant flow and mass transport, and nonlinear stochastic analysis and estimation. This will require application of advanced methods from fluid mechanics in porous media, probablistic analysis, applied estimation and geostatistics, and numerical analysis.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1499

TITLE: Sampling Strategies/Parameter Estimation in Ground-Water Quality Management: Theory and Field Validation

PERFORMING ORGANIZATION: University of California, Los Angeles

PRINCIPAL INVESTIGATOR: William Yeh

DURATION: September 1987 to September 1989

DESCRIPTION

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

Because of widespread contamination of ground water by industrial and other sources, there is a need for improved ground-water quality management techniques. In particular, a firmer theoretical foundation is required for the design of remedial activities based on management of the aquifer-flow field (for example, extraction of contaminated ground water and prevention of plume migration). Accurate models for prediction of contaminant transport in ground water are key to solution of this problem.

2. Contribution to Problem Solution.

This research is directed to: (1) determine how ground-water management models may be calibrated, verified and improved for real-world application; (2) assess the amount of data required for model testing; and (3) establish guidelines for the optimal collection of additional data to satisfy management objectives while minimizing data-collection costs.

3. Objectives.

A major objective of this work is to develop systematic procedures, based on numerical and optimization methods, for solute transport parameter identification (the "inverse problem") and sampling strategies for field-data collection (for example, modified aquifer tests in which tracer and contaminant concentrations are determined in addition to hydraulic head). These procedures will be useful for water managers in Federal, State, and local agencies. The primary field parameters to be addressed are transmissivities for the flow problem and dispersivities and sorption distribution coefficients (in effect retardation factors) for the solute transport problem. An additional objective is to test the procedures by application to the design and interpretation of modified aquifer tests to be conducted at a site contaminated with common ground-water pollutants such as volatile halogenated organic chemicals, for example, trichloroethylene (TCE), and so forth. The third objective is to conduct

laboratory studies of aquifer media from the field site in order to determine the sorption behavior of one or more of the site's organic contaminants and, thereby, to assess the validity of assumptions made in the theoretical development (for example, linear, reversible, instantaneous sorption) and corroborate the sorption distribution coefficient(s) estimated from the aquifer test by the parameter identification procedure.

4. Approach.

The theoretical research approach will include the establishment of an acceptability criterion defined by management objectives to be met by the optimal pump test design and the development of an efficient solution technique for identifying the transport parameters. The approach in the field work will be to collaborate with several industries or governmental facilities and their consultant(s) to review candidate sites and select the one best suited for testing of the parameter identification procedures, considering hydrogeology, contaminants present, and the number and location of installed monitoring and extraction wells. The approach will be to conduct the tests at no or low cost to the collaborator (we already have established collaboration of this type). Finally, the approach of the laboratory work will be to apply batch techniques to the determination of equilibrium sorption distribution coefficients and the rate of approach to sorption or desorption equilibrium (including conformance to first-order or radial diffusion rate laws).

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-1500

TITLE: Development of an Expert System Embedding Pattern Recognition Techniques for Ground-Water Pollution Source Identification.

PERFORMING ORGANIZATION: University of California, Davis

PRINCIPAL INVESTIGATOR: Gerald T. Orlob

DURATION: September 1987 to September 1989

DESCRIPTION

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

A considerable amount of attention is being focused on the prevention and treatment of ground-water pollution in the United States. In many cases the first required step in safeguarding the quality of ground water is the identifying of the pollution sources. It is difficult to formulate a mathematical model for this purpose that is robust enough to handle all field conditions, parameter uncertainties, and measurement errors. Existing models for identification of pollution sources do not explicitly incorporate physical and data-measurement uncertainties and errors.

This work proposes an alternative approach suitable for ground-water pollution source identification, and capable of utilizing highly developed stochastic tools to deal with systems having physical and data-measurement uncertainties.

2. Contribution to Problem Solution.

When fully developed, this expert system will provide a powerful tool for detecting ground-water pollution sources, thus enhancing remedial actions. The proposed approach of coupling pattern recognition techniques with the knowledge base to make inferences about pollution-source magnitude and location will find useful applications in many other expert systems for solving engineering problems.

3. Objectives.

The primary objective of the proposed research is the development of a user-friendly expert computer-based system to identify locations and magnitudes of ground-water pollution sources when a limited amount of pollutant-concentration data suggests the presence of such sources. This objective will be attained through the following steps.

1. Develop a finite optimal sequential pattern recognition algorithm to statistically match concentrations measured in the field with a comparable set obtained from a simulation (response) model of ground-water solute transport.

2. Develop a knowledge base, composed of a set of production rules, that can access and activate the pattern recognition algorithm.

3. Apply the solution heuristics contained in the knowledge base to make an inference about the locations and magnitudes of the pollutant sources.

4. Test the developed expert system for a selected study area of an aquifer, with known aquifer parameter values.

5. Compare the results with those obtained from a known optimization model used for the same identification purpose.

4. Approach.

The pattern recognition algorithm to be used is considered adequate at this exploratory stage of the investigation. More advanced algorithms at future stages to make the expert system more rigorous will be introduced. The primary goal at this stage of research is to investigate the utility and efficiency of this approach of embedding pattern recognition techniques in an expert system. Based on experience with this system, future extension of the system to include steady state cases and non-conservative pollutants are anticipated. Additionally, it will then be possible to explore in more detail questions of uncertainty in boundary conditions, field measurements, and model parameters.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1503

TITLE: Evaluation and Design of Geophysical Monitoring Network for Ground-Water Contamination

PERFORMING ORGANIZATION: University of Nebraska

PRINCIPAL INVESTIGATOR: I. Bogardi

DURATION: September 1987 to August 1990

DESCRIPTION

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

The research addresses the detection and monitoring of ground-water pollution, one of the Nation's primary environmental concerns. Reliable, fast and cost-effective detection and monitoring contribute to minimizing the adverse environmental impact of ground-water pollution, identifying the most hazardous situations, and determining the effectiveness of remedial actions.

2. Contribution to Problem Solution.

The use of state-of-the-art geophysics combined with advanced geostatistics and multicriterion decisionmaking is proposed for assessing the prediction capacity and for designing observation networks for ground-water pollution studies. The monitoring networks are to combine, in an optimal way, surface geophysical measurement and monitoring wells.

3. Objectives.

The following methodological objectives are defined:

1. Given a set of surface geoelectric measurements over a contaminated aquifer, to estimate the areal distribution of (a) ground-water specific conductance (SC), a common indicator of contamination, and (b) the prediction error of SC.

2. Given a set of several types of measurements (sounding, profiling, monitoring-well data) over a contaminated aquifer, to estimate the areal distribution of SC and the prediction error.

3. Given a set of measurements (one or several types) over a contaminated aquifer, find a cost-effective expansion scheme for monitoring.

4. Given an aquifer to be monitored, find a cost-effective monitoring network consisting of a proper combination of measurement techniques.

4. Approach.

Surface geoelectrical methods are attractive because of their relatively low cost, and because aquifer resistivities can be and have been correlated with ground-water specific conductance which, in turn, is a common indicator of ground-water pollution. Surface geoelectrical methods and instrumentation have improved significantly in the recent past. However, to fully realize their potential they must be employed quantitatively. In applications to pollution, the first step is to determine the appropriate geological model, and the variability of the model in the study area. This is difficult to do, except for the simplest geology, with geoelectrical measurements alone. As a consequence, pollution predictions based on surface geoelectrics alone are generally not possible and would be very uncertain. This research aims at quantifying this uncertainty and finding the "best" observational schemes which we propose would be a proper combination of direct and geophysical measurements. The usefulness of geoelectrics in aquifer pollution studies ultimately depends on the extent to which they quantitatively improve the accuracy and increase the related utility of pollution plume estimates.

SCIENCE AND TECHNOLOGY OF WATER-QUALITY MANAGEMENT

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1474
TITLE:	Treatment of Chlorophenol-Contaminated Waters and Soils Using Immobilized Microorganisms
PERFORMING ORGANIZATION:	BioTrol, Inc.
PRINCIPAL INVESTIGATOR:	R. L. Crawford
DURATION:	September 1987 to September 1988

DESCRIPTION

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

The program is directed toward defining the potential role of microbiology in the management of hazardous chemicals in ground-water environments with emphasis on the treatment of contaminated ground water. The research examines methods for removal of pollutants to prevent further contamination, leading to commercialization of reliable, less expensive biological alternatives to present physical and chemical technologies, such as combustion, flocculation, oxidation, and carbon filtration. Various chlorinated phenols are widely-used and versatile biocides in the United States. One example, pentachlorophenol, has been a major domestic wood-preserving agent for about 50 years, and contamination of soil and water in the vicinity of wood-treating plants is a severe environmental problem.

2. Contribution to Problem Solution.

The research will contribute to further development of biological treatment technology in solving contamination problems associated with soils and waters containing toxic, persistent, xenobiotic chemicals. Focusing this research program on the contaminants of the wood-preserving industry (penthachlorophenol plus other chlorinated phenols and polynuclear aromatic hydrocarbons associated with creosote) not only provides a real life setting to test the discoveries of this program, but also addresses an important environmental problem.

3. Objectives.

The objective of the project is to develop an effective immobilized cell system that will be used for routine treatment of natural or industrial waste waters containing toxic chemical pollutants.

4. Approach.

The approach used will be to examine the feasibility of treating waters that contain mixtures of toxic chemicals (for example, chlorinated phenols plus polynuclear aromatic hydrocarbons and/or chlorinated solvents) by using customized bioreactors containing mixtures of different bacteria, each immobilized in or on separate supports that are mixed before loading into the reactor. The effectiveness of immobilized bacteria in removing chlorophenol and other hazardous chemicals from contaminated soils also will be examined.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1475

TITLE: Nucleic Acid and Monoclonal Antibody Probes for Bacterial Pollutants of Water Resource Systems.

PERFORMING ORGANIZATION: University of Maryland

PRINCIPAL INVESTIGATOR: Rita R. Colwell

DURATION: August 1987 to July 1990

DESCRIPTION

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

The problem being addressed by this research is the identification of polluted water resource systems and detection of potentially pathogenic bacteria in ground-water supplies. It is intended to develop novel methods to identify an index bacterium (Escherichia coli) and a bacterial pathogen (Salmonella) in contaminated water. Specifically, it involves development of deoxyribonucleic acid (DNA) probes to unique 16S ribosomal RNA (rRNA) gene sequences of E. coli and then use of these probes, as well as existing probes to Salmonella for the detection of these bacteria in water. In addition, monoclonal antibodies (mAbs), including those developed by the project and those commercially available, will be used to detect E. coli and Salmonella. These two approaches will not only detect bacteria culturable by standard techniques, but also those E. coli and Salmonella that are not culturable by standard techniques.

Results of the proposed studies will be unique because standard methods identify bacteria which are easily cultured or in an active state of growth. However, it is now well established that the majority of bacteria in nutrient-deficient aquatic systems are not readily cultured by traditional methods. These studies will, therefore, provide a means of detection of these bacteria that are present, viable, and go undetected.

2. Contribution to Problem Solution.

The proposed research will allow a more accurate assessment of bacterial pollution of water resource systems than presently employed bacteriological methods, since both culturable bacteria and those that are not readily culturable by standard methods will be detected.

3. Objectives.

(1) Develop and test DNA probes to detect bacteria, including E. coli and Salmonella, in natural water systems.

(2) Produce and test mAbs to detect E. coli and Salmonella in water, including ground water.

(3) Optimize the use of DNA and mAb probes to detect E. coli and Salmonella in laboratory microcosms and contaminated water systems.

(4) Compare results using DNA and mAb probes to those obtained by standard techniques.

4. Approach

The approach taken in this research will be to develop and test DNA and mAb probes to detect E. coli and Salmonella in natural water systems, including ground water. DNA probes to sequences encoding 16S rRNA will be constructed for the identification of E. coli. Multiple copies of genes encoding 16S rRNA will increase the sensitivity of E. coli DNA probes. Both the E. coli probe and a commercially available DNA probe for Salmonella will be tested in hybridization experiments to determine the specificity and applicability of each. mAbs to heat-stable lipopolysaccharides of E. coli will be prepared. These mAbs to E. coli and existing mAbs to Salmonella will be evaluated in a fluorescent antibody-direct viable count (FA-DVC) procedure. Both the DNA and mAb probes will provide a more rapid, sensitive, and specific method to detect pathogenic bacteria in water systems.

Initially, the detection of E. coli and Salmonella with radiolabelled DNA probes and fluorescent antibodies will be optimized in laboratory microcosm studies. Once this work has been completed, environmental samples from fresh waters, including ground water and estuarine waters, will be analyzed with these probes.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1482

TITLE: The Use of Bacterial Bioluminescence and Gene Probes in Optimizing the Maintenance and Expression of Biodegradative Plasmids in Ground Water.

PERFORMING ORGANIZATION: University of Tennessee

PRINCIPAL INVESTIGATOR: Gary Sayler

DURATION: September 1987 to August 1990

DESCRIPTION

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

The contamination of ground waters by recalcitrant, toxic organic and chlorinated-organic compounds poses serious problems in ground-water quality and water-use alternatives as well as potential public health threats due to the ingestion of potential mutagens and carcinogens. Removal of such contaminants by physical and chemical means can be prohibitively expensive and may be inefficient if contaminants are in low concentration or sorbed to the solid phases in the ground-water aquifer. Biological degradation represents a potentially efficient technology for in-situ destruction of contaminants. However, within the scope of an overall remediation program, the versatile biodegradative abilities of naturally occurring and genetically modified microorganisms must be reliably measured and controlled if they are to be successfully stimulated or introduced in the ground-water environment. Many of the biodegradative abilities demostrated by bacterial populations can be attributed to extrachromosomal genetic elements (plasmids) that encode the responsible biochemical pathways. These plasmids can be naturally disseminated within a microbial community and can be further modified by powerful recombinant DNA technology to develop enhanced biodegradative capacity.

2. Contribution to Problem Solution.

Although biodegradation of a variety of contaminants has been reported in ground water, it remains difficult, if not impossible, to predict the rate, extent, or scope of biodegradation of many toxic and recalcitrant contaminants. This research program seeks to determine those environmental and ecological parameters that contribute to the long-term maintenance of biodegradative potential and activity of bacterial populations in ground-water environments. Knowledge of these parameters can be used to stimulate or introduce bacteria having specific biodegradative potential for selected pollutants in contaminated ground-water environments.

3. Objectives.

The objectives of this research are: (1) to develop two model bacterial plasmid systems to determine maintenance and expression of biodegradative genes under simulated in-situ ground-water conditions; (2) to determine those nutrient and environmental conditions that lead to optimum maintenance and expression (activity) of catabolic plasmid genes; and (3) to validate predictions derived from model systems as accurate in optimizing the maintenance and activity of catabolic plasmids introduced in natural ground-water aquifer microcosms.

4. Approach.

The demonstrated potential exists to stimulate natural biodegradation or introduce specific biodegradative organisms (or genes) into ground water. To determine if such genes can be optimized in terms of abundance and activity, the toluene/xylene (TOL) catabolic plasmid pWW0 and the polychlorinated biphenyl catabolic plasmid, pSS50, will be introduced into simulated and natural ground-water aquifer material. Both plasmid maintenance and expression (in term of biodegradation) will be measured using conventional microbial enumeration techniques; specific gene probe technology using DNA: DNA hybridization; assays for metabolism of the substrate contaminants; and expression of a lux gene cassette. The lux gene cassette inserted behind an appropriate promoter region of the catabolic plasmids will allow measurement of catabolic gene expression by direct measurement of bacterial luminescence encoded by the lux genes. By manipulating nutrient conditions, flow rates, population densities, and contaminant (toluene and PCB) concentrations. optimum conditions leading to plasmid maintenance and expression will be defined. Such predictions derived from simulated ground-water aquifer columns, will be validated and refined using natural aquifer material in a microcosm format.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1493

TITLE: Effect of Aquatic Exposure and Disinfection on the Virulence of Enteric Pathogenic Bacteria

PERFORMING ORGANIZATION: Montana State University

PRINCIPAL INVESTIGATOR: Gordon A. McFeters

DURATION: August 1987 to July 1990

DESCRIPTION

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

Previous studies have shown that waterborne bacterial pathogens and coliforms can become injured in water. Exposure to sublethal levels of various chemical and physical factors present in source and finished drinking waters stresses these bacteria, and they become reversibly debilitated. One manifestation of this injury is the inability to grow and form colonies on selective media containing surfactants. This phenomenon can lead to the underestimation of indicator bacteria and result in a false estimation of water potability. Most studies of bacterial injury in water have concentrated on the occurrence, detection, and physiological characteristics of injured waterborne coliform bacteria. Very little is known about changes in the disease causing potential of water-borne enteric pathogenic bacteria resulting from aquatic exposure.

2. Contribution to Problem Solution.

This proposal describes work to examine the virulence properties of enteropathogenic bacteria injured in water and their recovery. The findings from this study will provide useful information concerning the ability of enteropathogenic bacteria to cause illness following aquatic stress under conditions encountered in wastewater and drinking water treatment. These results are of significance in view of the increasing incidence of both waterborne morbidity and contamination of ground-water and surface-water resources.

3. Objectives.

a. To describe the virulence of enteropathogenic bacteria in response to copper and chlorine mediated injury. The bacteria to be studied include Shigella flexneri and Vibrio species. The technique to be used will be similar to those employed in earlier studies with other enteropathogens.

b. To determine the mechanism of injury leading to reduced virulence of non-invasive enterotoxigenic E. coli (ETEC).

c. To examine the stability of virulence plasmids in enteropathogens associated with injury. S. flexneri, Yersinia enterocolitica, and ETEC will be used in these experiments.

d. To test for changes in outer membrane proteins and lipopolysaccharides (LPS) following injury.

e. To examine the influence of the route of pathogen introduction on the outcome of *in vivo* infections with injured and control enteropathogens.

4. Approach.

Objectives a through e above will be investigated as follows:

a. This will be done by correlating viability and the degree of copper and chlorine-induced injury with various *in vivo* and *in vitro* indices of virulence.

b. This will be carried out by: (1) examining the effects of copper and chlorine on adhesions and surface components of ETEC involved in virulence; and (2) describing the enterotoxin synthetic rate in injured and recovering ETEC populations.

c. This will be done by determining the intracellular stability of plasmids associated with virulence following both long and short term injury by exposure to a range of copper and chlorine concentrations.

d. This aspect of the study will be done by using *E. coli* K-12 carrying a *Shigella* plasmid encoding virulence genotypes. Polyacrylamide gel electroploresis gels and protein mapping will be used to identify and follow changes in the outer membrane proteins and LPS associated with virulence phenotypes after injury.

e. Invasive (*Shigella* sp.) and non-invasive (ETEC) bacteria will be tested by different routes before and after injury with copper and chlorine.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1494

TITLE: Microbial Dehalogenation of PCBs at Low Redox Potentials

PERFORMING ORGANIZATION: University of Pittsburgh

PRINCIPAL INVESTIGATOR: Ronald Neufeld

DURATION: September 1987 to August 1990

DESCRIPTION

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

Serious deteriorations of surface- and ground-water quality currently exist from past discharges of polychlorinated biphenyls (PCBs) into surface waters and onto soils from land-disposed PCB-laden wastes.

PCBs are only slightly water soluble, but have a strong tendency to adsorb or partition onto organic-containing particles. PCB's are highly stable, and most are naturally degraded, but very slowly. Not all PCBs degrade at the same rate; in general, isomers that have a smaller percentage of chlorine degrade faster, while the more highly chlorinated isomers (penta-, hexa- or octo-chlorinated biphenyls) appear not be degraded under natural conditions. Two mechanisms exist for PCB mobilization in contaminated ground- and surface-waters; (a) chemical equilibrium with surrounding surface or ground waters, and (b) adsorption or partitioning onto and into suspended sediment particles. This results in PCBs becoming available for uptake by aquatic organisms, and movement into the water column.

2. Contribution to Problem Solution.

PCB contaminated sediments and soils may be economically remediated via biotechnological means. To date, however, bioengineered, natural, and laboratory bio-systems have not been able to degrade the higher chlorinated isomers (congeners) of PCBs in soils and sediments. This research is aimed at overcoming this limitation by (a) developing a chemically induced biological approach to initially and partially dehalogenate highly chlorinated PCB congeners followed by (b) the subsequent and complete degradation of intermediates by the larger consortia of biota at-large. Based on an extensive literature review coupled with theoretical considerations, it is believed that highly negative in-situ redox potentials coupled with acclimated microorganisms can accomplish the initial PCB dehalogenation step.

3. Objectives.

The overall objective of this research is to develop a technique for the bioengineered microbial degradation of PCB-contaminated soils and aquatic sediments. Degradation of highly clorinated PCB congeners has been identified as a difficult and critical issue. This research will try to achieve microbial dehalogenation of highly chlorinated PCB congeners to forms that are

more easily degraded by natural benthos or soil microbial consortia. The specific objectives are to (1) test the hypothesis that highly negative redox potentials with acclimated microorganisms can accomplish PCB congener dehalogenation, and (2) identify and quantify the key variables of this system leading to an understanding of the kinetics and mechanisms involved. Virtually all the PCB bioengineering research to date has emphasized rapidly growing aerobic PCB degradation on the lower chlorinated (and more readily) biodegraded PCB congeners.

4. Approach.

In this research, special redox depressing (non-toxic) additives will be incorporated with soils and sediments contaminated with higher-chlorinated PCB congeners. Contaminated sediments will be initially inoculated with cultures received from researchers at the General Electric/Albany Research Laboratory (Hudson River research) to establish the dehalogenation culture; this work will be followed by kinetic/mechanistic evaluations.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1495

TITLE: Determination of the Toxicity, Water-Quality Interactions and Biomagnification of Selenium in Aquatic Food Chains

PERFORMING ORGANIZATION: University of California, Davis

PRINCIPAL INVESTIGATOR: Allen W. Knight

DURATION: August 1987 to August 1989

DESCRIPTION

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

Elevated concentrations of the trace element selenium (Se) have been reported in water and aquatic organisms from many areas in the western and southwestern United States. Selenium has been implicated in the death and reproductive failure of fish and aquatic birds in North Carolina, Texas, and the Kesterson National Wildlife Refuge in California. The rapid accumulation and resultant toxicity of Se in the upper trophic levels is attributed to the direct uptake of the element from the aquatic environment (bioaccumulation) and the synthesis of organic Se compounds by primary producers, which subsequently can be biomagnified in the higher food-chain organisms. The toxicological problems associated with Se are particularly critical as little information is available on the toxicology, bioaccumulation and biotransformation of the various forms of Se found in aquatic ecosystems. A thorough knowledge of the toxicological dynamics of Se in aquatic ecosystems is necessary for the formation of responsible management strategies in areas where elevated Se levels occur due to natural processes, agricultural drainage, and coal-fired power generation.

2. Contribution to Problem Solution.

It is proposed to continue current studies examining the toxicity, bioaccumulation, biotransformation, and transfer of Se in the three principal components of an aquatic food-chain: primary producers (algae), primary consumers (herbivorous and detritivorous invertebrates) and secondary consumers (fish).

3. Objectives.

The objective of the proposed research is to provide basic information on Se toxicity, bioaccumulation and biotransformation in aquatic food-chains, which is hypothesized to cause decreased reproduction, teratogenesis and death in the upper trophic levels of impacted aquatic systems. Such data are currently unavailable and can be generated by the proposed laboratory food-chain experiments.

of Se with several water-quality parameters, including some that are potentially toxic, for example, molybdenum and boron.

Secondary Consumers: Determine the toxicity, bioaccumulation, and biotransformation of waterborne and dietary Se (seleniferous algae and invertebrates) on growth and reproduction of the fathead minnow, Pimephales promelas.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1496

TITLE: Molecular Biological Probes for Assessing Effects of Environmental Xenobiotics at Sublethal Levels on Fish Reproduction.

PERFORMING ORGANIZATION: University of Maryland

PRINCIPAL INVESTIGATORS: Thomas T. Chen and Dale B. Bonar

DURATION: September 1987 to August 1990

DESCRIPTION

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

The widespread use of polyhalogenated and/or polynuclear aromatic hydrocarbons as pesticides or for various industrial purposes in recent years has resulted in serious accumulation of these compounds or their metabolites in aquatic ecosystems. Fish contaminated with these compounds showed a wide range of pathobiological effects including dysfunction in calcium homeostasis, induction of hepatic mix function oxidases, degeneration of hepatocytes, reduction of egg deposition and egg hatch. However, detailed biochemical and molecular biological studies on the effects and the toxic mechanisms of these compounds at sublethal levels on fish growth, development, or reproduction await to be carried out.

2. Contribution to Problem Solution.

Although there are methods available for measuring the quantities of environmental xenobiotics, none of these methods is suitable for detecting the earliest pathobiological effects caused by the above mentioned compounds. Hence there is an urgent need to develop rapid, reliable, and sensitive assays for assessing the toxic effects of organic pollutants present in the aquatic ecosystems at sublethal levels. Preliminary studies conducted in the investigator's laboratory showed that sublethal levels of PCBs and/or Mirex caused marked reduction in the production of vitellogenin in juvenile rainbow trout induced by 17B-estradiol. This biochemical parameter may be used to index the adverse effects of environmental xenobiotics on fish reproduction.

3. Objectives.

The long term objectives of this research are to: (1) develop convenient, reliable and sensitive *in vitro* bioassays; (2) dissect the molecular toxic mechanisms of sublethal level environmental xenobiotics on growth, development and reproduction of fish; and (3) assess and identify other environmental organic pollutants that may affect the growth, development or reproduction of fish.

4. Approach.

To achieve these objectives, a series of short-term research goals have been developed, using estrogen-responsive and non-responsive genes as bioassay systems in rainbow trout and striped bass as model experimental animals. These short-term goals are: (1) isolation of lipovitellin from striped bass and raising a polyclonal antibody against this protein; (2) molecular cloning of cDNA of estrogen-responsive and non-responsive genes in the liver of striped bass; (3) studying the kinetics and the dose-response relationship of the expression of estrogen-responsive genes induced by 17B-estradiol in rainbow trout hepatoma cells and striped bass primary hepatocytes; (4) studying the effects of model polyhalogenated and/or polyaromatic hydrocarbons on the expression of estrogen-responsive and non-responsive genes in rainbow trout hepatoma cells and striped bass primary hepatocytes induced by 17B-estradiol; and (5) establishing defined protocols for screening environmental chemicals that may affect the expression of estrogen-responsive and non-responsive genes in both in vitro systems. PCB isomer [3,3,4,4'-tetrachloro-biphenyl], Mirex, benzo [a]pyrene, B-naphthoflavone, and DDT will be used as model test compounds in these studies.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1498

TITLE: The Molecular Structure Basis for the Mutagenicity of Lignin and Humic-Derived Chlorofuranones

PERFORMING ORGANIZATION: State University of New York, Syracuse

PRINCIPAL INVESTIGATOR: Robert T. LaLonde

DURATION: September 1987 to September 1990

DESCRIPTION

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

The chlorination of water for industrial and hygenic purposes is a widespread practice in all developed nations. Acceptance of water chlorination is understandable in view of chlorine's high oxidation potential, effectiveness as an antimicrobial and delignifying agent, low cost, and simplicity of use. Still a greater need for water chlorination can be anticipated if an additional supply of water is to be provided by wastewater reclamation for the manifold uses of a growing population that expects its standard of living to be maintained or even bettered. It seems unavoidable that water chlorination will at least be recommended as a step in water reclamation. However, the practice of water chlorination is potentially hazardous since a highly potent mutagen results from the action of chlorine on the lignin component of humics contained in water. Concern for this hazard will be mitigated somewhat by the knowledge that some natural sources of water introduce less lignin-containing humics than other sources. Furthermore, any mutagens generated during chlorination may prove to be readily inactivated by mammalian liver or intestinal tissue or blood.

2. Contribution to Problem Solution.

The catabolism of these mutagens has received little attention. The aim of this study is to provide basic chemical information about these mutagens showing the functional and structural components responsible for their mutagenicity. The data will be applied to effect practical *in vitro* methods of inactivation. This study will identify the specific structures that are responsible for mutagenicity so that an intelligent, planned approach to inactivation can be developed.

3. Objectives.

The proposed research concerns principally 3-chloro-4-(dichloromethyl) -5-hydroxy-2(5H)-furanone, a mutagen produced by the industrial chlorination of lignin and the hygienic chlorination of humic-containing drinking water. This study will find the essential structural components of a 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone that are responsible for its mutagenicity. The study also will find structural molecular components of this furanone that undergo *in vitro* chemical change when the furanone is treated in a manner that results in its loss of mutagenicity.

4. Approach.

Systematic mutagenic testing of structural components and correlation of component hydration with component mutagenicity are the general approaches to identify the structural components of 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone that make it such a potent mutagen. The identification of the products of inactivation is the general approach to determine by what practical treatment this mutagen can be inactivated and what structural and functional components are changed as a result of inactivation. Thus, the results of the proposed research will provide basic scientific information that will have an impact on the chlorination of water in both industrial and hygienic practices. The synthesis of several 2-dichloromethylpropenals, determination of the degree of their aldehydic hydration, assessment of their relative mutagenicities and the correlation of hydration with mutagenicity are the objectives to be met in order to test the hypothesis that it is the aldehydic, open ring form of 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H) furanone that is responsible for its mutagenic activity. Treatment of the latter compound with alkali and isolation and characterization of the products is another objective which is to be met in order to test the hypothesis that modification of certain alkali-sensitive segments of mutagenic furanone will inactivate it.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1501

TITLE: Surface-Chemical Factors Affecting Transport of Bio-Colloids in Subsurface Porous Media

PERFORMING ORGANIZATION: The University of Arizona

PRINCIPAL INVESTIGATOR: Roger C. Bales

DURATION: September 1987 to August 1989

DESCRIPTION

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

The movement of biological colloids is important in ground-water quality because: (1) small particles facilitate the transport of sorbed contaminants; (2) virus and bacteria colloids are of public health concern in drinking-water supplies; (3) introduction of mobile bacteria or enzymes into contaminated aquifers is a potential in-situ cleanup strategy; and (4) colloidal material contributes to aquifer clogging. Field observations suggest that colloidal material can migrate tens of meters or further from the source under certain physical and chemical conditions.

2. Contribution to Problem Solution.

While several mathematical models of colloid migration in subsurface porous media have been proposed, models incorporating physical/chemical descriptions of the colloid/collector surface interactions have not been evaluated experimentally, either in the laboratory or in the field. Interpretive and predictive tools to describe colloid transport/retardation in response to chemical perturbations (e.g., rainfall, recharge, etc.) are needed. This research will address this need by: (1) providing carefully determined and complete data for use in modeling/interpretation; (2) integrating existing models that describe aqueous chemical interactions, surface-chemical properties, and forces between particles with a simple physical model; and (3) experimentally evaluating the model under simulated and real conditions encountered in field situations.

3. Objectives.

The overall objective of the research is to gain a fundamental, quantitative understanding of the importance of surface-chemical interactions for the transport of colloidal particles through soil and aquifer material.

4. Approach.

It is proposed to use virus particles for the experimental work, because (1) they are important contaminants in drinking water, (2) they are relatively straightforward to enumerate as compared to other colloids, and (3) their chemical properties are well known from previous work. The research

results will be general and applicable to other colloids, however. The approach will involve: (1) experimental investigations of colloid movement both in the laboratory and in the field, and (2) synthesis of existing mathematical models to interpret and predict colloid transport under a wider range of conditions that can be studied experimentally. This will be accomplished by: (1) developing laboratory and field data for use in modeling/interpretation, (2) integrating an existing surface/solution chemical model with one for colloid stability and a simple physical model into a general calculation procedure for one-dimensional colloid transport, and (3) experimentally evaluating the model under natural-water conditions. Experimental work will use primarily MS-2 virus as a model colloid, as it is well characterized, relatively straightforward to enumerate, and has been used as a ground-water tracer in the past. Laboratory adsorption and column studies will use surface-modified silica and other well-characterized metal oxides. Other primary variables will be pH, ionic strength, media size, and temperature. All experiments will be under "saturated" conditions. The field site is a shallow sandy aquifer near the laboratory which has been used previously for virus transport studies.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1504

TITLE: A Novel Non-Lethal Field Bioassay for Predicting Stream Water Quality Impaired by Heavy Metals and Low pH

PERFORMING ORGANIZATION: Pennsylvania State University

PRINCIPAL INVESTIGATOR: William Dunson

DURATION: August 1987 to August 1990

DESCRIPTION

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

There is a strong need for a non-lethal bioassay that can be used to assess the degree to which stream-water quality has been affected by acid-mine drainage typified by low pH and heavy-metal pollution. Because of the complex chemical nature of most impaired streams, this assay must be able to distinguish some aspects of the interactions between the various constituent pollutants. Previous methods often involve the use of test organisms in an all-or-none approach to toxicity that does not adequately quantify the effect of sublethal exposures to the organism. A new bioassay is proposed that will precisely indicate the effect of pollutants on trout and provide an exact indication of water quality.

2. Contribution to Problem Solution.

The research will provide data that can be used to predict the biological impact of impaired water quality in certain streams even at sublethal levels of pollutants.

3. Objectives.

(1) To determine which heavy metals are toxic in one representative acidic, heavy metal-polluted stream by evaluation of sublethal physiological responses of trout.

(2a) To develop simple predictive criteria for estimating the toxicity of acidic, heavy metal-polluted streams to trout (based on standard water chemistry analysis).

(2b) To develop a system (model) for categorizing water quality-impaired streams on the basis of toxicity to trout.

(3) To field test and evaluate the model on at least three streams selected from each category.

(4a) To determine whether present water-quality standards set for individual heavy metals are adequate.

(4b) To determine whether present water-quality standards are valid when other heavy metals are present in varying ratios.

4. Approach.

The research will investigate the use of a non-lethal bioassay, based on a specific physiological response of trout to pollutants, to differentiate the interactions of multiple heavy metals in an acidic stream environment. Development of this bioassay will be based on results from the field, throughly tested and refined in the laboratory, and then field tested again in several different streams.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1492

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

PERFORMING ORGANIZATION: Georgia Tech Research Corporation

PRINCIPAL INVESTIGATOR: L. M. Speaker

DURATION: September 1987 to August 1988

DESCRIPTION

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

Electrodialysis (ED) membranes used in desalination and in impaired-water renovation are rapidly fouled by colloidal and semicolloidal materials omnipresent in feed streams. The resulting poisoning and physical occlusion lead to virtually exponential rises in the electrical resistances of ED stacks and, thus, to greatly magnified energy and dollar costs for their operation. A post-manufacture modification has been developed for application to commercial ED membranes to preserve the low electrical resistances that they display when pristine. The acronym for this modification is AFT (anti-fouling technology).

2. Contribution to Problem Solution.

Previous research supported by the Department of the Interior reduced to practice the concept that Langmuir-Blodgett (LB) layers of appropriate fluorinated material satisfactorily minimized the fouling of anion-exchange membranes exposed to accelerated lifetime testing. An ongoing program is extending the earlier work to ultra filtration (UF) and reverse-osmosis (RO) membranes. It is anticipated that the proposed program will complete the pretechnology development phase of AFT, bringing it to the point at which application in real water-renovation systems can be undertaken.

3. Objectives.

The objectives of the proposed research are the following: to perform lifetime studies of the original surface modification of ED membranes; to optimize this modification by studying the effects of different, but related, LB-layering compounds; to include studies of the efficacy of AFT for preventing fouling of cation-exchange membranes; and, for advancement of the theoretical understanding of membrane separation systems, to separate and identify the influences of polarization and fouling.

4. Approach.

Selected fluorinated amphiphilic materials will be attached to commercially available membranes as oriented monomolecular layers, and the effects on fouling properties, power requirements, selectivities, and lifetimes will be determined.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1502
TITLE:	Water and Wastewater Filtration: A Particle Perspective
PERFORMING ORGANIZATION:	University of Texas
PRINCIPAL INVESTIGATOR:	Desmond F. Lawler
DURATION:	September 1987 to August 1989

DESCRIPTION

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

In potable water supplies and in wastewaters discharged to surface waters, many pollutants are particles or are attached to particles. The need to remove such particles increases as waters with impaired quality are considered for potable water supplies and higher quality is demanded in wastewater discharges. Depth filtration is the treatment designed for final separation of particles from water, but fundamental knowledge of that process is limited. All of the theoretical modeling and the well-controlled experiments performed to date have been limited to monodisperse suspensions, conditions not representative of filtration in practice. In addition, the theoretical and experimental work has largely ignored the tendency of a filter to improve its capture efficiency with time as previously retained particles begin to capture other suspended particles ("ripening"). Neglecting ripening, a critical aspect of successful filter performance, is also not representative of practice. Improved knowledge of filtration is necessary. The approach of this research is to extend the theoretical knowledge (mathematical models) of filtration into filtration of heterodisperse suspensions during ripening and to test the improved models with results from highly controlled experiments with latex spheres and with real waters.

2. Contribution to Problem Solution.

By its design, the research will contribute both to the theoretical knowledge of filtration of heterodisperse suspensions during ripening and to the link between theory and practice. The experimental data will help meet the need for results from experiments performed under well specified and controlled conditions during ripening.

3. Objectives.

The objectives of this research are to (1) improve existing mathematical models of filter ripening by incorporating effects of particle-size heterogeneity, (2) measure particle-size distributions and head loss as functions of time and depth in a filter bed as a suspension passes through the bed under varying physical conditions, and (3) test the validity of the mathematical model with the experimental results.

4. Approach.

Mathematical modeling and laboratory experiments will be integrated in this research. Some aspects of several different models of filtration will be incorporated into the extension for heterodisperse suspensions. A series of well-controlled experiments with increasing complexity are planned for a systematic investigation of the model. Testing experiments are designed in recognition of the idealizations of the model. Well-established procedures for detailed measurements of particle-size distributions, developed in this laboratory in several previous studies, will be employed.

CLIMATE VARIABILITY AND THE HYDROLOGIC CYCLE

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1483

TITLE: Large-Scale Ocean Atmospheric Variability Associated with Hydrological Extremes in Western North America

PERFORMING ORGANIZATION: University of California, San Diego

PRINCIPAL INVESTIGATORS: J. Namias, D. Cayan, and J. Roads

DURATION: September 1987 to August 1989

DESCRIPTION

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

The bulk of the watershed storage in western North America is accumulated from a few months of winter-season precipitation. The amount of precipitation received in this area is strongly affected by variations in the atmospheric planetary circulation on time scales from a few days to decades. The mechanisms responsible for hydrological extremes and extended spells of wet and dry over this wide range of time scales are not well understood and, hence, such extremes are inadequately predicted. With the ever increasing demand for water in the western United States, future variations in the amount of precipitation will become increasingly important.

2. Contribution to Problem Solution.

The proposed project represents a coordinated effort by three members of the Scripps Institution of Oceanography Climate Research Group to study the sensitivity of streamflow and precipitation to changes in the large scale oceanic and atmospheric circulations over a wide range of time scales. Atmospheric and ocean surface temperature patterns associated with anomalous wet and dry periods in the western United States during the past 100 years will be identified and diagnosed.

3. Objectives.

A comprehensive analysis of the relations of changes in the atmospheric circulation and the ocean-surface temperature with those of the hydrologic cycle in western North America will be conducted. The principal objectives are as follows:

- o to diagnose the effect of winter-atmospheric circulation over the North Pacific on western North America streamflow variability,
- o to improve understanding of multiyear episodes of heavy and light precipitation and streamflow in the West, and
- o to verify and diagnose numerical predictions of circulation and precipitation anomalies from the National Meterological Center's medium and extended range model in order to help improve forecasts of precipitation on weekly and monthly time scales.

4. Approach.

Empirical and statistical analyses of the longest available monthly streamflow, precipitation and atmospheric sea-level pressure records will be performed. In addition, a series of extended atmospheric model predictions of atmospheric flow and precipitation that affects the western North America region will be compared wih observed daily conditions in verifying forecasts from a few days to a few weeks.

INSTITUTIONAL CHANGE IN WATER-RESOURCES MANAGEMENT

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1476

TITLE: The Comparative Performance of Institutional Arrangements for Ground-Water Resources

PERFORMING ORGANIZATION: Indiana University

PRINCIPAL INVESTIGATOR: Elinor Ostrom

DURATION: September 1987 to August 1989

DESCRIPTION

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

Institutional arrangements are used by a community to determine who has access to a resource, what quantities users may consume and at what times, and who is to monitor and enforce the rules. Research in the design and performance of these arrangements has not kept pace with advances in hydrological engineering. As a result, new technical solutions cannot be implemented with the confidence that efficient and equitable outcomes will be forthcoming. Basic questions exist about the comparative performance of alternative institutional arrangements, as well as the best methods for fitting particular institutional "solutions" to specific problematic situations. Existing theoretical arguments yield contradictory conclusions. This indicates that a need exists for empirical research using a systematic, comparative analysis of selected cases containing representative instances of both institutional success and failure.

2. Contribution to Problem Solution.

The research will contribute information about the range of alternative institutional arrangements, the conditions of their development, and the comparative performance of existing institutional arrangements.

3. Objectives.

The research will use a series of case studies to examine alternative institutional arrangements for the allocation and reallocation of water among competing uses in the context of common-property resource management. Specifically, the research will seek to learn: (1) the kinds of institutional arrangements that user communities, when given ample discretion, have worked out to attempt to solve joint problems of water allocation and regulation of the uses made of common-property resources; (2) the difficulties involved in the development of market arrangements in a common-property context and alternative institutional means of resolving these difficulties, and (3) the obstacles and inducements to the initiation of new institutional arrangements by the user-community, including the legal definition of property rights to promote water exchange, for the management of common-property water resources.

4. Approach.

The methods of institutional analysis developed by colleagues associated with the Workshop in Political Theory and Policy Analysis will be utilized to conduct a series of comparative analyses of the efficiency and equity of existing institutional arrangements in natural settings to cope with ground-water basin management problems.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1481

TITLE: Improving Management of Intrastate and Interstate Water Transfer in Eastern United States.

PERFORMING ORGANIZATION: Virginia Polytechnic Institute and State University

PRINCIPAL INVESTIGATOR: William Cox

DURATION: September 1987 to September 1989

DESCRIPTION

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

Water transfer is a basic means for increasing water supply in areas of shortage; however, water-management institutions in many eastern States appear to provide an inadequate basis for resolving conflict associated with large-scale transfer in a manner that ensures efficient use of resources in water-supply development and equitable treatment of affected parties. This research will assess the water-supply situation in the eastern States to define the future role of water transfer. A case study approach, guided by an economic model of water transfer, will be used to analyze institutional weaknesses affecting evaluation and disposition of proposals for intrastate and interstate transfer and to provide a basis for recommending improvements.

2. Contribution to Problem Solution.

The research will expand available information concerning the need for water transfer and the operation of related water-management institutions. A general decision framework that mitigates existing obstacles to efficient and equitable resolution of transfer-related conflict will be developed for application in the eastern States.

3. Objectives.

The objectives of the proposed research are to:

(a) Assess the potential role of water transfer as a water-management device in the eastern United States by evaluating the likely types and locations of major supply shortages.

(b) Conduct case studies of successful and unsuccessful water transfer proposals to illustrate fundamental institutional factors affecting related efficiency and equity issues.

(c) Develop a decision process that integrates State water-allocation law, land-use controls, environmental protection measures, and other relevant decision processes into a coordinated approach to managing intrastate water transfer.

(d) Extend the decision framework applicable to intrastate water transfer to the interstate context.

4. Approach.

Analysis of the water-supply situation in the eastern United States and the potential role of water transfer will involve review of existing water-supply studies. Identification of institutional factors associated with water transfer will involve two types of investigation within a case-study context: (1) analysis of applicable statutes, court decisions, and administrative arrangements; and (2) interviews with key individuals within the case study areas. A general decision framework for disposition of transfer proposals will be derived from the case studies by combining components from existing institutional arrangements into new approaches exhibiting the collective strengths of existing approaches while avoiding their weaknesses.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1487

TITLE: A Survey and Assessment of Public Water-Supply Management During the Southeast Drought of 1986.

PERFORMING ORGANIZATION: North Carolina State University

PRINCIPAL INVESTIGATOR: David Moreau

DURATION: September 1987 to August 1989

DESCRIPTION

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

Extensive portions of the southeastern United States experienced severe drought conditions throughout the first 10 months of 1986. A partially completed survey of the southeastern States indicates that a large number of public water supplies were affected by the drought, some rather severely. The severity of the problem was compounded in some instances by the failure of local water managers to have previously established criteria to guide decision during the drought, the lack of interlocal agreements regarding transfers among water supplies, the lack of adequate information systems, and the lack of available technologies to estimate the probabilistic outcomes of management options. Without that information, some systems may have adopted management tactics that increased the risk of running out of water.

2. Contribution to Problem Solution.

Unfortunately, most of the information about the management of public water supplies during this event is anecdotal, and the management techniques which might have alleviated some of the problems are not commonly included in the educational backgrounds and continuing education of local water managers. This project seeks to systematically survey and evaluate experience during the 1986 drought and to use those results, as well as other experiences in the United States, to expand the use of available management techniques.

3. Objectives.

The primary objective of the proposed project is to systematically survey and evaluate the criteria and management of public supplies during this period. The survey will give special attention to intergovernmental arrangements for regional cooperation during droughts, decisionmaking criteria, and techniques used to cope with the drought and their impacts, information systems, and formal methods for predicting the outcomes of management decision. The evaluation will be an assessment of the extent to which emerging management techniques were used and of the potential that could have been realized had they been in place in 1986.

A second objective is to expand the use of currently available technologies and institutional arrangements for managing droughts.

4. Approach.

The survey will conducted using mail questionnaires with follow-up mail and telephone contacts. In selected cases, site visits may be necessary. Expansion of the use of management techniques will be promoted through the development and implementation of microcomputer simulation exercises and a regional workshop.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1538

TITLE: The Water Transfer Process as a Management Option for Meeting Changing Water Demands

PERFORMING ORGANIZATION: Colorado Water Resources Research Institute

PRINCIPAL INVESTIGATOR: L. MacDonnell

DURATION: September 1987 to March 1990

DESCRIPTION

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

A fundamental problem in the western United States is the allocation of limited water resources in response to ever growing and changing demands. Social objectives are dynamic, and their continued satisfaction over time requires flexibility in the transfer and exchange of water. Western State governments have institutionalized appropriative water-right systems and have developed administrative structures and operating procedures for refereeing water-resources use and allocation. As water demands have become increasingly diverse and enlarged, and as stream systems have become more completely allocated, the transfer option grows more attractive. In some cases, the number and complexity of transfer and exchange schemes have taxed the adaptive capacity of State water-right systems. Criticism and concern are growing over delays, difficulties, and increased costs associated with water transactions. There is a need to examine the water reallocation process and the nature of those elements that may impede its smooth functioning.

2. Contribution to Problem Solution.

Impediments to the transfer of water/water rights may be found in statutes, procedures, institutional and organization mandates, operating policies, and in costs of making the transaction. Generic solutions to problems can best be obtained through a comparative evaluation of experience with the transfer issue in different States. Hence, the study will examine the mechanisms employed in the transfer process in Arizona, California, Colorado, New Mexico, Utah, and Wyoming. Case studies of a variety of specific transactions will provide a means of measuring the relative importance and magnitude of factors reflecting the water-transaction process and particularly their influence on transaction costs.

3. Objectives.

The objectives of the research are: (a) to ascertain the levels and kind of water transfer and exchange activities in six selected States in the western United States; (b) to determine the major legal and institutional factors influencing the efficiency and equity of such transfer activities in these States; (c) to measure the transaction costs imposed on water transfer ac-

tivities by each State system related to these legal and institutional factors; (d) to compare findings from the six States studied and identify specific measures for expediting the transfer and exchange process consistent with protection of other water rights, public interests, and values that may be affected.

4. Approach.

The research will be conducted on an inter-university basis. The research team will be comprised of a lead investigator from each State with support staff and consultant assistance as deemed appropriate. An advisory panel composed of water officials with direct experience and oversight responsibility in the water-transaction process will be organized to interact with the research team and to provide counsel and advice as the study progresses.

The study will be an empirically-based analysis of water transfers in each State with information gathering carefully coordinated and evaluation jointly accomplished to assure meaningful and corroborated results and conclusions. Individual State water codes, administrative procedures, and case law pertaining to water allocation and transfer will be analyzed in a comparative way. Also, organizational and institutional arrangements and operating policies for administering and managing water entitlements will be compared. A second prong of evaluation will be to analyze and compare case histories of water-transaction experiences in each State.

SURFACE-WATER MANAGEMENT

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1479

TITLE: Application of Economic Analysis to Water Allocations and Fish Habitat Enhancements, John Day River Basin

PERFORMING ORGANIZATION: Oregon State University

PRINCIPAL INVESTIGATORS: R. M. Adams, P. C. Klingeman, and H. W. Li

DURATION: September 1987 to August 1990

DESCRIPTION

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

As public agencies in the Northwest attempt to meet legally-mandated increases in fish production, competition for streamflow between "traditional" out-of-stream uses and in-stream uses has intensified. Attempts to increase fishery benefits through water reallocation are confounded by existing water institutions. As a result, economic analyses of water reallocations must consider changes in the institutional setting that restrict in-stream possiblities.

2. Contribution to Problem Solution.

Research on the benefits and cost of interseasonal streamflow adjustments is limited by a lack of biological data on fish response to flow, habitat, or other management options. The interdisciplinary approach to this valuation problem will generate biological and hydrological data for use in the economic assessment. The study can serve as a methodological model for future integrated evaluations of water-use fishery management issues. The empirical results may also be extrapolated to other stream systems in the Columbia River Basin.

3. Objectives.

The overall objective of the research is to evaluate the benefits and costs associated with alternative seasonal water allocations and anadromous fishery habitat-management options, using Oregon's John Day River basin as a case study for exploring technical and economic relations between in-stream flows, water use, fish production, and other competing benefits.

4. Approach.

Emphasis will be on the relation between changes in streamflow and habitat options (for example, riparian habitat management) and the production and valuation of anadromous fisheries resources arising from each option. However, values of water in traditional uses will be developed to allow comparisons of net economic benefits across all uses within the study basin. Potential economic gains for reallocations of water to fishery production will then be assessed under alternative institutional settings, including temporary water markets.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1480

TITLE: Gas Transfer in Streams with Surface Instabilities: White-Water Effects and Riffle-Pool Sequences

PERFORMING ORGANIZATION: Cornell University

PRINCIPAL INVESTIGATOR: G. H. Jirka

DURATION: September 1987 to August 1990

DESCRIPTION

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

The transfer of gases across the air-water interface is one of the controlling pathways that affect the distribution of material in the environment. A wide class of gaseous materials is involved, ranging from dissolved oxygen (the most persistent problem of water-quality management) to gases such as CO_2 (critical for climate dynamics as well as pH response of acid-rain runoff and/or mine drainage), and to volatilizing toxic materials (of rapidly increasing concern as health and ecological effects become better understood). The project is specifically concerned with gas transfer in flowing streams, for which the state-of-the art of predictive ability is especially unsatifactory. This, in turn, causes a large uncertainty in waste-load allocation plans and in toxic-control strategies and requires costly field-tracer studies to obtain the transfer characteristics of a particular stream.

2. Contribution to Problem Solution.

Natural streams may have complex hydraulic characteristics and a few simple parameters as used in present predictive equations (such as slope, mean velocity, and mean depth) cannot be expected to describe both the details of the gas transfer process in an individual stream and the large variability among streams. From basic experiments and from the oceanographic literature it appears that surface instabilities, which lead to greatly enhanced localized transfer rates, are of particular importance. Such instabilities and the associated white water effects around macro-roughness elements and in riffle-pool sequences are ubiquitous in natural streams. An explicit description of this enhancement effect will greatly improve the accuracy of stream gas-transfer prediction.

3. Objectives.

Objectives of the research will be: (1) to measure in laboratory experiments the enhancement of local gas transfer by macro-roughness elements and by simulated riffle-pool sequences; (2) to derive, on the basis of the experimental information of related detailed field-tracer experiments in Survey offices and of mechanistic principles, predictive equations that include stream surface instabilities as an explicit parameter; and (3) to incorporate such equations into a detailed micro-computer based program (for example, HEC-2) that includes necessary hydraulic details for accurate gas-transfer prediction in engineering practice.

4. Approach.

Two existing experimental facilities at Cornell University will be used. First, the effect of the location of the turbulent energy source will be investigated in a series of experiments in a grid-stirred tank. Second, a special tilting wind-water tunnel for gas-transfer research will be used, in the water-flow mode only, to study in a large-scale and well-controlled environment the quantitative enhancement caused by white-water effects and riffle-pool sequences. A systematic variation of roughness features typical for natural streams will be studied. The experimental data will be categorized and compared with data from equivalent conditions in recently completed or concurrent field experiments by three Survey offices (Kentucky, Massachusetts, New York). Gas transfer equations with dependence on a macro-roughness parameter will be developed using a conceptual transfer model (on the basis of stream energy dissipation) and will be compared to the data categories. Finally, a detailed predictive methodology using a stream hydraulics program (for example, HEC-2) will be developed as an accurate and economical method for engineering and planning applications.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1488

TITLE: Contaminant Exchange Processes Between Water and Sediment Beds in Rivers

PERFORMING ORGANIZATION: California Institute of Technology

PRINCIPAL INVESTIGATORS: N. H. Brooks, J. J. Morgan, and R. C. Koh

DURATION: July 1987 to January 1990

DESCRIPTION

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

Toxic-contaminant transport in natural rivers involves solute exchange processes between the stream flow and the sediment bed. The sediment beds and banks of a river can act as the storage place for contaminants dumped into a river system. There are two basic cases, the transport into the bed (capture) and out of the bed (release). These are both non-equilibrium situations, where the chemical and physical processes both may govern the rate of capture and release. Computer models for predicting toxics concentrations are limited by the accuracy of the representation of the water-bed exchange process. Little basic research has been done to understand the interplay of fluid transport and chemical processes.

2. Contribution to Problem Solution .

This research is directed toward the development and testing of mathematical models to represent exchange processes in streams. These models will be in a form suitable for use in comprehensive water-quality modes for rivers.

3. Objectives.

The purpose of the proposed research is to develop a better physical and chemical understanding of the basic processes controlling the interchange of contaminants or tracers between flowing fresh-water streams and their sediment beds. The project will address some of these key questions:

(1) What are the strengths and limitations of conceptual models of water-bed exchange of contaminants as currently used in water-quality models for rivers?

(2) In detail, what are the physical and chemical processes controlling the transfer in either direction?

(3) How can bed exchanges be represented better in water-quality models, reflecting physical and chemical understanding?

(4) How do active bed-sediment transport and the occurrence and movement of bed-forms (dunes, ripples, etc.) affect the transfer rates and penetration of contaminants into stream beds?

(5) How can the vertical profiles of contaminants in stream-bed sediments be related to past history of water quality and discharge?

(6) The constituents in water in a river are generally well-mixed in the vertical, but only very slowly mixed or diffused into the sediment bed. What physical processes (and at what rates) cause transport of solutes and small particles into and out of granular stream beds? Does stream turbulence cause unsteady flow into and out of the bed resulting in mass transport of pollutants?

(7) How does increased transport of bed sediments in suspension (as during a flood) enhance exchange from bed to stream water?

4. Approach.

This research project will investigate the fundamentals of water-bed exchange of inorganic contaminants in a 5-meter long recirculating laboratory flume and a turbulence tank, both with fine sediment beds. Grain sizes and mixtures will be chosen which have good sediment characteristics for lab research and are typical of large river beds. Typical experiments will involve establishment of an initial disequilibrium between water and bed, and observing the changes in water and bed concentrations (both in dissolved and particulate phases) as the exchange processes work toward the new equilibrium.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1497

TITLE: Development of Tracer-Gas Technique for Bays

PERFORMING ORGANIZATION: University of Texas

PRINCIPAL INVESTIGATOR: E. R. Holley

DURATION: September 1987 to August 1989

DESCRIPTION

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

There are at least two important situations in which surface transfer characteristics for dissolved gases between water and the atmosphere need to be known, namely for reaeration and for desorption of volatile pollutants. The interest in gas transfer in bays is primarily in the context of desorption of volatile pollutants; it is not possible to analyze or predict the transport and fate of pollutants without knowing the volatilization rates. For bays, the influence of wind on gas transfer means that results from rivers are not applicable. There is good data on wind effects on surface gas transfer in laboratory mixing vessels and flumes and in the oceans, but there is essentially no data on gas transfer for bays. The small amount of data that does exist for bays shows a marked divergence from both the laboratory data and the oceanographic data. The shallow depth of bays compared to oceans is probably one of the primary reasons that ocean results are not applicable for bays. Thus, at present, there is no basis for predicting surface gas transfer for bays.

2. Contribution to Problem Solution.

The tracer-gas technique was introduced into measurement of surface transfer rates for rivers more than 20-years ago to overcome the accuracy problems with oxygen balances and with other techniques. In this method, a tracer gas is dissolved in the water body for which the gas-transfer characteristics are desired. The surface transfer of the tracer gas is measured and this information is used to determine the transfer of other gases. The tracer-gas method has proven to be a very powerful tool, but it has been used almost exclusively for small rivers and for determining gas-transfer coefficients for specific locations and flow conditions. Surprisingly, the tracer-gas method has apparently not been used for other types of water bodies nor for general studies of gas-transfer processes. This research will develop the tracer-gas technique so that quantitative information can be obtained on gas transfer at water surfaces allowing better predictions to be made of the desorption from water of volatile, dissolved pollutants following accidental spills or accidents involving barges or ships.

3. Objectives.

The primary objective is to use field tests and analytical work to develop the tracer-gas techniques for determination of surface exchange rate coefficients for volatile pollutants in bays.

4. Approach.

Field experiments for the development of the tracer-gas technique will be conducted in two bays adjacent to the Gulf of Mexico. The experiments will be used to test methods for injecting and measuring the required conservative and gas tracers and to develop methods which can reasonably be used under field conditions in bays. A total of about 25 field experiments will be conducted. Analytical work will also be done to develop improved methods of extracting surface-gas exchange rate coefficients from the field data.

PROJECT INFORMATION

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 Water Resources Research Institute

PRINCIPAL INVESTIGATOR: C. J. Popp

DURATION: August 1987 to August 1988

DESCRIPTION

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

Acidic precipitation occurs in various parts of the western United States. Whether acidic inputs are having detrimental effects on western ecosystems remains unknown. The high-elevation watersheds of northern New Mexico and southern Colorado may be particularly vulnerable to acidification. The soils of these watersheds are derived from volcanic and granitic rock and, therefore, should have low neutralization capacity. The aqueous chemistry of lakes in these watersheds should be dominated by atmospheric deposition because of the large quantity of wet precipitation received, small watersheds, poorly developed soils, short soil contact times, and isolation from ground-water sources. The lakes are also located downwind from significant regional point sources of acid precursors and trace metals. Preliminary data collected in the summer of 1986 placed 60 percent of the lakes sampled into "sensitive" or "highly sensitive" ranges in terms of available alkalinity.

The research will remedy the existing lack of information about the vulnerability of high elevation western ecosystems to acidification.

2. Contribution to Problem Solution.

Using a suite of chemical and biological analyses, the study would identify lakes that are potentially vulnerable to future inputs of acidic precipitation. Chronological analysis of diatom assemblages and trace metal concentrations in sediment cores will indicate whether lake chemistry has changed as a result of deteriorating regional air quality.

3. Objectives.

The specific objectives of the proposed research project are: (1) to expand the documentation of the existing buffering capacity of a series of high mountain lakes located downwind from major sources of acid precursors; (2) to determine via chemical and biological analysis of sediment cores whether the aqueous chemistry of the lakes has changed in the recent past; (3) to quantify the temporal variation of buffering capacity in a poorly buffered lake as a function of biological and climatological processes; and (4) to determine the sources and sink for sulfate in the lake via measurements of sulfur isotope ratios.

4. Approach.

High mountain lakes with low alkalinities and other indications of potential acidification will be sampled for chemical and biological analysis. Secchi disk transparency and depth profiles of pH, temperature, dissolved oxygen, and specific conductance will be measured. The phytoplankton, zooplankton, and benthos samples will be examined for species composition, relative abundance, and diversity. The data will be used to meet the specific objectives of this project.

SECTION II
COMPLETED PROJECTS

COMPLETED PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1139

TITLE: Microbiological Cleanup of Pentachlorophenol-Contaminated Ground Water

PERFORMING ORGANIZATION: BioTrol Incorporated

PRINCIPAL INVESTIGATORS: Thomas D. Frick and Ronald L. Crawford

START: September 1985

FINAL REPORT RECEIVED: December 1986

ABSTRACT:

This study demonstrated the feasibility of microbiological cleanup of pentachlorophenol-contaminated ground water. A 200 liter packed bed bioreactor was constructed and colonized with a microbial consortium that degrades pentachlorophenol. (This bioreactor effectively removed more than 99 percent of the pentachlorophenol from ground water containing 60 to 80 ppm of pentachlorophenol). The overall activity of the bioreactor reached 60 mg of pentachlorophenol consumed per hour per liter of reactor volume. In addition to pentachlorophenol, the bioreactor removed a number of non-target compounds. The chemical oxygen demand of the water was reduced from 270 mg/L in the influent to 190 mg/L in the effluent. Initial cost estimates indicate that this technology will be competitive with activated charcoal treatment.

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

ORDER NUMBER: PB-87177275

COMPLETED PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1131

TITLE: Development of the Vacuum Freezing Multiple-Phase Transformation Process for Desalination and Water Reuse

PERFORMING ORGANIZATION: Calyxes Research and Development Corporation

PRINCIPAL INVESTIGATOR: Chen-Yen Cheng

START: September 1985

FINAL REPORT RECEIVED: January 1987

ABSTRACT:

Although the advantages of a vacuum freezing desalination process over conventional means have been known for many years, and research and development of various vacuum freezing processes have been conducted for over 25 years, there is still no commerical vacuum freezing process in existence. Upon evaluation, it is seen that many of the problems encountered were associated with the methods used to liquefy the low-pressure vapor with heat recovery for melting washed ice. The Vacuum Freezing Multiple Phase Transformation (VFMPT) Process accomplishes vapor liquefaction by desublimation of the vapor on a refrigerated surface, production of a second water vapor of higher temperature than the melting point of ice, and then directly contacting the second vapor with the desublimate to simultaneously condense the second vapor and melt the desublimate. The second vapor is generated by a thin film evaporator, with the refrigerant vapor generated in the desublimation step, upgraded by a compressor, condensing inside the evaporator.

Bench-scale experiments with a 3.5 percent NaCl solution to simulate sea water show that the vapor liquefaction steps can be conducted reliably and at rapid rates. In addition, it was shown that second vapor can be used to melt ice at rapid rates. Construction of a 5,000 gallons per day unit for conducting the vacuum freezing and vapor liquefaction steps is in progress with main component of the unit near completion. The unit will be tested to show reliability of continuous operation as well as simplicity of required equipment.

During the course of the grant period, it was conceived that the vacuum freezing process could be extended to the treatment of eutectic mixtures to recover solute as well as solvent in a solid or nearly solid form. Preliminary experiments with the water-NaCl system show that co-crystallization of solvent and a dihydrate of the solute as separate crystals can be accomplished and the substantially lower-pressure vapor produced from the eutectic mixture can be liquefied using the VFMPT approach. This approach, in combination with the VFMPT Process which can concentrate a solution to its eutectic composition would be a most comprehensive method for desalination, industrial solution concentration, water reuse, and pollution abatement.

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COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1140

TITLE: Nitrate Retention as it Affects Ground Water Pollution in Mid-Atlantic Soils

PERFORMING ORGANIZATION: University of Delaware

PRINCIPAL INVESTIGATOR: Donald L. Sparks

START: September 1985

FINAL REPORT RECEIVED: September 1987

ABSTRACT:

Nitrate retention as it affects ground-water pollution was investigated on nine major Mid-Atlantic soil types. Objectives of this study were to determine the magnitude and rate of NO_3 retention and the effect of anion competition on NO_3 retention. The soils had a wide range in organic matter, clay, and oxide content. Charge properties including anion exchange capacity (AEC) and point of zero salt effect (PZSE) were determined by Mg-Ba exchange and potentiometric titration, respectively. The PZSE values were low, indicating little anion adsorption capacity while AEC values often were significant and increased with profile depth as oxide and clay contents increased. Kinetics of NO_3 retention and release and the effect of competitive anions on NO_3 retention were investigated at pH 4.0, 5.5, and 7.0 using a stirred flow method. Nitrate retention was highest at pH 4.0 and was strongly correlated with clay and oxide contents. The adsorption kinetics were rapid and completely reversible indicating the NO_3 adsorption mechanism is electrostatic. Several soils including the Cecil, Dothan, and Matapeake adsorbed considerable NO_3 at pH 4.0 whereas the Evesboro soil adsorbed little NO_3. Whenever SO_4 was present, NO_3 retention significantly decreased and was even depressed when Cl was added.

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