Water Resources Research Center

Annual Technical Report

FY 1998

Introduction

Research Program

Basic Project Information

Basic Project Information	
Category	**Data**
Title	In Situ Experimental Analysis and Modeling of Diesel Fuel Bioremediation in a Tidally Influenced Aquifer
Project Number	C-04
Start Date	08/01/1997
End Date	07/31/1999
Research Category	Ground-water Flow and Transport
Focus Category #1	Groundwater
Focus Category #2	Models
Focus Category #3	Water Quality
Lead Institution	University of Hawaii at Manoa

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Aly I. El-Kadi	Unknown	University of Hawaii at Manoa	01
Francoise M. Robert	Unknown	University of Hawaii at Manoa	01

Problem and Research Objectives

This project deals with the problem of contamination of subsurface nearshore sites in Oahu, Hawai‘i.

Our overall goal for this research is to develop and apply a remediation strategy for in situ bioremediation of petroleum products. A well-documented site has been identified where a diesel contaminant has leached to the water table, which lies about 8 feet below the ground surface. The contaminant (up to 2 feet of free product) is located in a deposit of sand and gravel which is subjected to tides. Before in situ experiments could be carried out, a model had to be developed on the basis of a laboratory simulation (Project C-02, WRRIP FY 96). The results of the study should be applicable to other situations because the site represents many that exist in Hawaii as well as coastal areas of the continental United States.

The specific objectives of the study are as follows:

1. To set up an in situ bioremediation experiment for residual diesel
2. To assess the disappearance of diesel contaminant under no-action and under bioremediation conditions
3. To determine changes in hydrocarbon-degrading populations of microorganisms in the contaminated soil
4. To model the fate and transport of the product at the field site

Methodology

Three areas that are contaminated with similar levels of diesel will be selected at the field site, using the most recent survey data available. Each of the three areas will be a 10 feet • 10 feet square. One area will be used as a control under normal conditions (no-action site). The second area will be treated with nutrients (nitrogen, phosphorus, and micronutrients) and oxygen. The third area will be treated with oxygen only. An innovative technique of bioremediation, based on that used to degrade petroleum hydrocarbons in soils under houses in American Samoa, will be tried at the field site. In the center of each section, a monitoring well will be driven into the soil to about 15 feet deep. The wells will also be used to provide nutrients and oxygen to the second area, and oxygen only to the third area. Through the use of an air compressor, oxygen will be delivered continuously unless measurements show that adequate levels are supplied by the tidal water. The loss of nutrients to the surrounding water will be monitored by sampling the water through existing wells downstream of the treated site. The levels of oxygen in the water will be monitored via the monitoring wells at the control and treated sites and a well in a non-contaminated area (background level).

To determine the progress of bioremediation, core samples of 8-foot-deep soil in the diesel-contaminated area will be drilled mechanically by a private company. Six soil samples will be obtained from each area on four separate occasions. At each sampling time the concentration of total petroleum hydrocarbons (TPHs) and polycyclic aromatic hydrocarbons (PAHs) will be determined by gas chromatography and immunoassay, respectively. The levels of phenanthrene-degrading bacteria and of diesel-degrading microorganisms will be determined using the techniques used during the first year.

We plan to apply a number of models for the field problem. The objectives of modeling are to calibrate the models based on available information. We will use a vertically integrated approach to assess the horizontal spread following leakage and to analyze a number of remediation strategies. The model will be linked to a two-dimensional solute transport model. Mass flux of the dissolved phase will be estimated at the water table, based on the extent of the free product. We will develop a new model for bioremediation of residual hydrocarbon under tidal conditions, because we believe none of the available models can deal with this situation.

Principal Findings and Significance

During the reporting period, we have not made much progress in the field work due to difficulties in contracting and securing an entry right to the site. The owner of the site, Hawaii's Department of Transportation (Airport Division), has tentatively agreed to provide additional financial support ($50,000), which will greatly facilitate our contracting and research efforts. Data collection and modeling efforts have continued during this period as described below. We have asked for a no-cost extension for the project and were tentatively informed that the extension was granted.

Modeling

We have developed an efficient field-scale model for residual hydrocarbon biodegradation in tidal aquifers. The model combines the equation for water flow in saturated/unsaturated media, the convection/dispersion equation for oxygen and nutrients, with a source/sink term, and a bacterial growth submodel. The results from two laboratory experiments are used to test the model. One of the experiments, which was funded through a previous WRRIP project (C-02), examined the potential for biodegradation of No. 2 diesel fuel in the tidal zone of a nearshore aquifer. In general, the model was able to simulate the results of the laboratory experiments. We have also simulated bioremediation in a typical nearshore aquifer for one year.

Model Assumptions

The model's main assumptions include neglecting changes in water density and hysteresis. The model simulates a single hydrocarbon component (or the total petroleum hydrocarbon). Further, hydrocarbon dissolved in the aqueous phase due to bacterial activities is directly metabolized by bacteria, i.e., concentration of dissolved hydrocarbon in the aqueous phase remains at zero at all times.

Model Testing

Test 1: Laboratory Case with No Water Flow

We successfully tested the model against the experiment of Chua-Chiaco (1998), who studied bioremediation in a clayey soil that was contaminated with 6,000 mg of diesel fuel No. 2, per kg of soil. The soil was seeded (5 • 107 cells/g of soil) with a Hawaii soil bacterium (UH138) known to utilize several hydrocarbons. The soil was limed, fertilized, and incubated in jars at 30°C for several months. The concentrations of TPHs and PAHs in soil were measured by gravimetry and immunoassay, respectively. Poisoned controls (0.6% HgCl2) were used to determine the extent of hydrocarbon degradation due to microbial activity. A rapid first order biodegradation of TPHs (84% in 23 days) occurred in soil contaminated with diesel, regardless of bacterial seeding. Biodegradation of PAHs was linear and reached 84% by day 98 in both seeded and unseeded treatments. The decrease in TPHs and PAHs was paralleled by an enhancement in CO2 evolution by the soil and by an increase in populations of total bacteria, phenanthrene-degrading bacteria, and microorganisms capable of utilizing hexadecane and diesel fuel No. 2.

Test 2: Tide Experiment

The second test dealt with the data from project C-02, which examined the potential for biodegradation of No. 2 diesel fuel in the tidal zone of a nearshore aquifer. The tidal zone of columns

of coralline sand was contaminated with diesel fuel (10% pore volume), and the water level was alternatively lowered and raised. The columns either received air, N, P, and micronutrients or were left untreated. The experiment showed that the migration of the product was minor and that most of the product remained in the tidal zone, which was consistent with one of the main assumptions of the developed model. A slow biodegradation of alkanes occurred over 90 days. The populations of hydrocarbon-degrading microorganisms were stimulated in the tidal zone of the aerated and fertilized columns only.

Test 3: Hypothetical Aquifer

Bacterial growth and biodegradation of TPH were simulated for one year in a tidal aquifer (dimension of 50 m • 30 m). The water table was located 10 m below ground surface. Tides were simulated at the right-side boundary, whereas the water level was unchanged at the left-side boundary. Ten percent of porosity was occupied by diesel. Nutrients were added to the middle section where bacteria is assumed to be active. Oxygen, which was injected in a well below the low tide, is also assumed to flow inland with the tidal water.

Conclusions

The bacterial growth model can be linked to appropriate solute and transport models, and solution is only completed where bacterial activities exist. The model is able to qualitatively predict the nutrient and bacterial growth in laboratory experiments. The results indicate great sensitivity of the results to nutrient and oxygen distributions, hence more emphasis should be put in the collection of such data.

New studies should deal with estimating the various parameters of the bacterial growth model, especially those related to Monod kinetics nutrients and oxygen sink/source parameters. The model will be used in the design and analysis of the field experiment.

References

Chua-Chiaco, B.W. 1998. Effect of bioaugmentation and diesel fuel type on soil bioremediation. Master's thesis, Department of Microbiology, University of Hawai'i at Manoa, Honolulu, Hawaii.

Descriptors

biodegradation, brackish water, decision models, diesel, groundwater quality, hazardous waste, hydrologic models, multiphase transport

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Chua–Chiaco, B.W., 1998, Effect of bioaugmentation and diesel fuel type on soil bioremediation, MS Dissertation, Department of Microbiology, University of Hawai'i at Manoa, Honolulu, Hawai'i.

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Wastewater Treatment for Odor/Nutrient Control
Project Number	C-05
Start Date	08/01/1997
End Date	07/31/1999
Research Category	Biological Sciences
Focus Category #1	Agriculture
Focus Category #2	Nutrients
Focus Category #3	Treatment
Lead Institution	University of Hawaii at Manoa

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Ping-Yi Yang	Unknown	University of Hawaii at Manoa	01

Problem and Research Objectives

Odor control and nutrient control are two obvious factors that determine the success of reuse/disposal of wastewater and sludge from conventional domestic sewage treatment and animal waste management systems. Controlling odor, nutrients (as nitrogen), and dissolved solids are the main problems closely related to the reuse/disposal of treated wastewater and sludge.

The anaerobic lagoon system has been widely applied and practiced in the United States. However, problems such as odor production, contamination of well water (seepage), and sludge handling have been found in operating this system to treat animal waste. It is apparent that further studies are needed to deal with the odor and water quality problems associated with animal production operations. Success in conducting this research will enable owners of domestic sewage and livestock wastewater treatment systems to reuse or dispose of the treated wastewater and sludge in an environmentally sound system. Therefore, the scope of this study is to develop a waste/wastewater treatment system that will manage the treated wastewater and sludge to be reused in an environmentally sound, socially acceptable, and economically feasible way.

The specific objectives of this study are as follows:

1. To evaluate the process performance of the activated reactor for the removal of odor, carbon, and nitrogen contained in domestic sewage treatment systems
2. To evaluate the pretreatment process of activated thermophilic aerobic digestion for further anaerobic digestion of animal manure
3. To develop the design and operational criteria for the activated reactor, perform a cost evaluation, and disseminate the information to users.

Methodology

For objective 1, a series of experiments were conducted to evaluate the entrapped mixed microbial cell (EMMC) process performance. Three systems, which are packed with a large carrier and two medium carriers (one without humic substance added and another with humic substance added), were preliminarily studied to evaluate the removal efficiency of soluble COD (chemical oxygen demand), BOD5 (5-day biochemical oxygen demand), total nitrogen, and total suspended solids. For the odor-causing compound (sulfide) removal, the suspended culture system, medium carrier I (without humic substance added) system, and medium carrier II (with humic substance added) system were investigated in the laboratory-scale unit. Synthetic wastewater simulating domestic sewage and actual domestic sewage were used in this experiment.

After the evaluation of the EMMC process performance, a laboratory scale of the conventional treatment facility incorporated with the humic substance carrier was installed to study the simultaneous removal of organics, nutrients, and odor-causing compounds from real domestic wastewater.

For objective 2, no experiment was conducted during this reporting period because the project received funding for only one year.

For objective 3, the optimal design and operation criteria were developed based on the results of objective 1. The cost of the proposed process was evaluated by calculating the net present worth. The results will be disseminated to the public and regulatory agencies through the annual Hawaii Water Environmental Association conference, through workshops or conferences organized by the Hawaii Water Resources Research Center, and through other national/international environmental-related conferences.

All of the laboratory experiments and analyses were conducted in the Environmental Engineering and Science Laboratory of the Department of Biosystems Engineering, University of Hawai‘i at Manoa, Honolulu, Hawai‘i.

Principal Findings and Significance

Because the project was funded for only one year, instead of two years as originally requested, only objective 1 and part of objective 3 were completed. Objective 2 will be accomplished if more funding can be secured.

The EMMC process was investigated for the simultaneous removal of organics, nutrients, and odor-causing compounds in a single reactor. Both synthetic and actual domestic wastewater were used for testing the EMMC technology.

It was found that the removal efficiency for synthetic wastewater was 97.3% for SCOD (soluble

chemical oxygen demand), 98.3% for SBOD5, 89.8% for total nitrogen, and 91.8% for total sulfide. However, the removal efficiency for actual domestic wastewater was 75.0% for SCOD, 93.8% for SBOD5, 53.4% for nitrogen, and 94.7% for dissolved sulfide. The lower removal efficiency obtained for domestic wastewater may be due to the lower COD/N ratio (COD/N = 7.0). The operation criteria were for one hour aeration and one hour nonaeration of the intermittent aeration system. The hydraulic retention time was maintained at 12 hours. It was also found that the addition of humic substance has some improving effect on the removal of organics, nitrogen, and odor. The cost of treating 1,000 gallons per day (3.785 m3/day) of wastewater is $0.50. Further work on the effect of COD/N on the simultaneous removal of carbon and nitrogen is in progress.

Descriptors

aeration, animal waste, biological treatment, denitrification, nitrogen, nutrient, oxidation, pollution control, wastewater treatment

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Cao, K.P. 1998, Simultaneous removal of carbon and nitrogen by using a single bioreactor for land limited application, MS Dissertation, Department of Biosystems Engineering, University of Hawai‘i at Manoa, Honolulu, Hawai‘i, 156 pp.,

Su, R., 1999, Simultaneous removal of organics, nutrients and reduction of odor production by EMMC technology, MS Dissertation, Department of Biosystems Engineering, University of Hawai‘i at Manoa, Honolulu, Hawai‘i, 132 pp.

Water Resources Research Institute Reports

Conference Proceedings

Yang, P.Y., and K. Cao, 1998, Entrapped mixed microbial cell process for combined secondary and tertiary wastewater treatment, in the WEF/EWPCA/CIWEM Specialty Conferences— Innovation 2000, Cambridge, U.K., July 7–10, 1998.

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Assessment of Chemical Pollution and Bioavailability in Pearl Harbor Using Supercritical Fluid and Immunochemical Methods
Project Number	C-06
Start Date	09/30/1998

Start Date	09/30/1998
End Date	09/29/1999
Research Category	Water Quality
Focus Category #1	Methods
Focus Category #2	Water Quality
Focus Category #3	Sediments
Lead Institution	University of Hawaii at Manoa

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Qing X. Li	Unknown	University of Hawaii at Manoa	01
Roger W. Babcock	Unknown	University of Hawaii at Manoa	02

Problem and Research Objectives

Contaminated sediment is a serious problem in many watersheds in Hawai‘i, in the continental United States, and throughout the world. Efforts to monitor pollutants in sediments and saltwater remain very difficult. Complete removal of polychlorinated biphenols (PCBs), polycyclic aromatic hydrocarbons (PAHs), and pesticides, particularly their metabolites, from sediments is a challenge due to the complexity of the matrices and analytes. Most solvent extraction methods require multiple concentration and cleanup steps prior to detection. Therefore, not only are they tedious to carry out but they also generate tremendous amounts of solvent wastes. Other methods for quantification of organic pollutants (e.g., gas chromatography–mass spectroscopy) are time-consuming and expensive.

Enzyme-linked immunosorbent assays (ELISAs) and supercritical fluid extraction (SFE) are methods that show great promise for environmental monitoring. Using these methods instead of those mentioned above immediately reduces environmental pollution and risk associated with the analysis process because they generate minimal amounts of hazardous solvent wastes. In addition, these methods are not only fast and simple, but also cost-effective because they allow for large sample throughput.

The overall objective of this project is to develop and evaluate "solvent-free" methods for monitoring PAHs, PCBs, and pesticides in sediments and waters at ultratrace levels to facilitate both assessment of bioavailability and pollutant monitoring in Pearl Harbor, Hawai‘i. Three specific aims are (1) to determine levels of PAHs, PCBs, and pesticides in harbor sediment and water using SFE and ELISAs; (2) to develop bioavailability techniques coupling SFE and Microtox; and (3) to transfer to other researchers techniques to study chemical pollution in other harbors and nearshore areas in Hawai‘i and elsewhere.

Pearl Harbor was selected as the model site for the study because it is heavily polluted. Its sediment and associated water column are ideal sources of "real" samples for conducting research into rapid and easy immunochemical techniques (suitable for field use) for the extraction, identification, and quantification of toxic organic chemicals for purposes of pollution monitoring and bioavailability assessment. Data collected on the status of chemical pollution and bioavailability in the harbor will be used to determine the degree of remediation necessary in Pearl Harbor. Success of the project will enable extension of the technologies to studies of other contaminated coastal areas and harbors.

Methodology

The project progresses from simple to complex. The experimental designs are hypothesis-based. In the SFE studies, we have selected about 30 model compounds, including common pesticides, chlorinated phenols, and PAHs. A dry land soil (Leilehua soil) was used as the model matrix, and supercritical carbon dioxide (SC-CO2) was used as the extracting fluid. SFE conditions for quantitative recovery of these model compounds were optimized by varying the chelating reagent, co-solvent, moisture, pressure, and temperature. The chemicals in the extracts were measured by capillary electrophoresis or gas chromatography (GC).

In the ELISA work, we have chosen to analyze atrazine in groundwater. Antibodies were obtained from Dr. A.E. Karu at the University of California–Berkeley and haptens from Dr. B. Hammock at the University of California–Davis. We reacted the atrazine hapten with horseradish peroxidase (HRP) to obtain a haptenated HRP enzyme tracer. We optimized the assay, which can detect about 0.1 ppb of atrazine in groundwater without sample preparation. About 50 groundwater samples have been analyzed using the atrazine ELISA, which has proved to be very economical.

Next, we will adopt these assays for the analysis of pollutants in saltwater and harbor sediments. In the bioavailability work, we are determining the most accurate and effective technique to utilize SFE prior to employing Microtox assays to assess bioavailability. The use of SFE should have advantages over other extraction methods for preparation of Microtox extracts. When the assays are proven to be adequate and effective for the analysis, we will employ the techniques to study chemical pollution in other harbors and nearshore areas in Hawai‘i as well as the U.S. mainland.

Principal Findings and Significance

A novel SFE procedure was developed to quantitatively recover polar and nonpolar chemicals from soils. The polar chemicals tested were aromatic acids and phenols. The nonpolar and slightly polar chemicals used as model compounds were common pesticides and environmental pollutants such as PAHs. The procedure required pretreatment of the samples with 15% water (g/g), 5% Na4EDTA (g/g), and 50% methanol (ml/g) prior to extractions using SC-CO2 at 60°C and 34.5 MPa. Recoveries ranged from 90% to 106% for the aromatic acids using the Na4EDTA-assisted SFE compared with only 7% to 63% for the corresponding chemicals when no Na4EDTA was used. The method quantitatively extracted 2,4-D and its close analogs aged in the soil for 2 to 30 days. The Na4EDTA-assisted SFE was also adequate for extracting phenolic analytes including picric acid and pentachlorophenol with recoveries from 85% to 104%. The method is valuable for the analysis of parent pollutants and transformed products, particularly oxygen-borne metabolites in the environment.

An ELISA method was developed and used to screen for the presence of atrazine in 52 wells. Fifteen well samples showed an assay inhibition equivalent to 0.1 ppb of atrazine. Of these fifteen positive

samples, nine that were re-analyzed by GC confirmed the presence of atrazine, deethyl atrazine, and/or simazine. Deethyl atrazine was detected by GC in 34 of the 52 samples. The results showed that ELISA is a reliable method for screening atrazine in groundwater but not for screening other triazine herbicides and their degradates because of the assay specificity.

Descriptors

Articles in Refereed Scientific Journals

Guo, F., Q.X. Li, and J.P. Alcantara–Licudine. 1999. A simple Na4EDTA-assisted sub/supercritical fluid extraction procedure for quantitative recovery of polar analytes in soil. Anal. Chem. 71:1309–1315.

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Information Transfer Program

Information transfer activities undertaken by the Water Resources Research Center in the reporting period include organization of the Center's ongoing biweekly seminar series on water-related topics, organization of special seminars, publication of a newsletter of Center news, sponsorship and coordination of a statewide water awareness poster contest for school students, production of slides and poster materials for the illustration of projects, responding to telephone and mail requests for water information, expansion and maintenance of the Center's web site, and making presentations to community groups.

Seminars

Dr. Aly I. El-Kadi, professor with the Department of Geology and Geophysics and researcher with the Water Resources Research Center, was the coordinator for the spring 1998 seminar series. During the reporting period, the following eight seminars were held.

- 03/05/98: Chester Lao, Hydrologist-Geologist, Honolulu Board of Water Supply, Board of Water "Supply Viewpoints on Waiahole Water"
- 03/19/98: R.T. Nishimoto, Division of Aquatic Resources, Department of Land and Natural Resources, "Na I‘a ‘Oiwi O Hawai‘i: The Fish Borne by the Floods"
- 03/20/98: Dr. Frank Kreith, P.E., ASME Legislative Fellow, National Conference for a Sustainable Future, "Solid Waste Management for a Sustainable Future"
- 04/02/98: George Hudes and Charles Reppun, Community Activists, "The Waiahole Ditch Case: Problems with the Process"
- 04/16/98: Michael Parke, Ph.D. Candidate, Department of Geography University of Hawai‘i at Manoa,

"Land Suitability for Waste Water Reuse"
- 04/23/90: James Hunt, U.C. Berkeley, "Sediment Contamination in San Francisco Bay"
- 04/28/98: Peter Walthern, University of Wales, Aberyswyth, "Environmental Impact Assessment"
- 05/05/98: Dr. Bruce Macler, Drinking Water Toxicologist, USEPA, Region IX, San Francisco, "Health Risks and Management Strategy for Pathogenic Microorganisms in Drinking Water"

The coordinator for the following seminars in the fall 1998 series was Philip S. Moravcik, technology transfer specialist with the Water Resources Research Center.

- 09/03/98: Peter Rappa, Coastal Resource Management Extension Agent, Sea Grant Extension Service, University of Hawai‘i at Manoa, "Policy Considerations for Beach Erosion in Backyards of Hawaii"
- 09/17/98: Charles Fletcher, Professor, SOEST, Department of Geology and Geophysics, University of Hawai‘i at Manoa, "Far From the Ivory Tower: Erosion Management in the Backyards of Hawaii"
- 10/01/98: Art Challacombe, Branch Chief, Coastal Lands Branch Department, Department of Planning and Permitting, City and County of Honolulu, "Beach Management in Hawaii: A Public Sector Perspective"
- 10/15/98: Michael Hamnett, Director, Social Science Research Institute, University of Hawai‘i at Manoa, "Efforts to Develop and Implement Hazard Mitigation in the State of Hawaii"
- 11/05/98: Sam Lemmo, Senior Planner, Land Division Planning Branch, Department of Land and Natural Resources, "Coastal Erosion Management in Hawaii: Where are we?"
- 11/19/98: Robert Mullane, University of Hawai‘i Sea Grant Extension Service, Kahului, Hawai‘I, "The Beach Management Plan for Maui"
- 12/03/98: Stan Boc, U.S. Army Corps Engineer, "Beach Nourishment Design"
- 12/17/98: Michael Wilson, Hawaii Department of Land and Natural Resources, "Sustaining Hawaii’s Beaches– Is it Possible?"

Dr. Chittaranjan Ray, assistant professor with the Department of Civil Engineering, was the coordinator for the following seminars in the spring 1999 series.

- 01/21/99:, Stephen Anthony, Supervisory Hydrologist, U.S. Geological Survey, "What is the NAWQA Program?"
- 02/04/99: Qing X. Li, Professor of Environmental Biochemistry, University of Hawai‘i at Manoa, "Assessment of Chemical Pollution and Bioavailability Using Supercritical Fluid and Immunochemical Methods"
- 02/18/99: Bill Wong, Chief, Clean Drinking Water Branch, State of Hawaii Department of Health, "State of Hawaii’s Source Water Assessment Program (SWAP)"

Newsletter

Three newsletter issues were written, published, and distributed by the technology transfer office in the reporting period. The newsletters contain information about WRRC projects and faculty, as well as water-related issues in the state. Approximately 900 copies were distributed to persons with an interest in water issues in Hawai‘i. Newsletter recipients include water and wastewater management agencies, other governmental agencies concerned with water issues, legislators, academic researchers, environmental consultants, and interested members of the public.

Slide Shows

Computer-generated slides and slide shows were produced to illustrate a number of WRRC projects at a variety of conferences and workshops throughout the reporting period.

School Poster Calendar Contest

Every year since 1993 the technology transfer office has coordinated a statewide calendar—poster contest for school children in Hawai‘i. This is a program of the International Office for Water Education (IOWE), Utah Water Research Laboratory at Utah State University. Children from around the state submit posters to the Water Resources Research Center based on a theme provided by IOWE. The technology transfer office displays these posters at the WRRC offices and the winners are decided with the help of Center faculty and staff. The winning posters are sent to IOWE, along with photographs of the students who submitted them and of the Governor, and these are included in a water calendar that is distributed to schools throughout the western United States. The technology transfer office sends letters of congratulations and thanks to all the children who submit posters, as well as a prize to the winner. This poster contest helps foster an interest and awareness of water and other environmental issues among the state's school children.

WRRC Web Site

The technology transfer office continues to expand the Water Resources Research Center's presence on the World Wide Web. A number of pages describe the Center's origins, missions, and activities. The Center has taken on the responsibilities of being a regional pollution prevention center under the federal USEPA's P2 program, and the technology transfer office has created a number of pages in support of this function as well. Abstracts of all WRRC publications are now available at the website. The Center's home page may be viewed at: http://www2.hawaii.edu/~morav/WRRC.html.

Database

The technology transfer office maintains a database of local newspaper articles pertaining to issues of water and wastewater. This database is made available both to individuals from within the university community and to others needing to locate such articles for their research.

Students Supported

Two undergraduate students were supported by the technology transfer office during the reporting period.

Principal Information Transfer Publications

- Fujioka, Roger S., director, 1998, Hawai‘i Water Resources Research Center Annual Program Report for 1997—98, GR02666-02, Water Resources Research Center, University of Hawai‘i at Manoa, Honolulu, Hawai‘i, 36 pp.
- Water Resources Research Center Bulletin, n.d., Water Resources Research Center, University of Hawai‘i at Manoa, Honolulu, Hawai‘i, 6 pp.
- Water Resources Research Center Bulletin, n.d., Water Resources Research Center, University of Hawai‘i at Manoa, Honolulu, Hawai‘i.
- Water Resources Research Center Bulletin, n.d., Water Resources Research Center, University of Hawai‘i at Manoa, Honolulu, Hawai‘i, 8 pp.

USGS Internship Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	1	0	0	3
Masters	0	4	0	0	4
Ph.D.	0	0	0	0	0
Post-Doc.	0	2	0	0	2
Total	2	7	0	0	9

Awards & Achievements

Publications from Prior Projects

Articles in Refereed Scientific Journals

Yang, P.Y., and C. Gan, 1998, An on-farm swine waste management system in Hawaii, Bioresource Technology 65:21–27.

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications