# Water Resources Research Center

# Annual Technical Report

# FY 2000

## Introduction

For the period covered by this report, the University of Hawaii Water Resources Research Center has continued to pursue the strategic goals and research themes identified in earlier years.

Two faculty members retired: Civil Engineering Professor Yu-Si Fok and Environmental Center Specialist Jacquelin Miller. National searches for their replacements have begun. In addition, Civil Engineering Professors Clark C.K. Liu and Associate Professor Chittaranjan Ray will join WRRC on a half-time basis beginning August 2001, and Associate Specialist John Harrison will return from an administrative assignment with the University.

The USGS State Water Institutes grant has been leveraged with appropriated state funds of nearly $800,000. Other projects with external funding of approximately $1,074,000 were in progress as of June 2001, roughly a 25% increase over the previous year.

All things considered, UH WRRC can look forward to many changes and increased activity in the near future.

## Research Program

### Basic Information

| | |
|---|---|
| **Title:** | Polymer Effects on Virus and Bacteria Transport in Subsurface |
| **Project Number:** | C-08 |
| **Start Date:** | 3/1/1999 |
| **End Date:** | 2/28/2001 |
| **Research Category:** | Ground-water Flow and Transport |
| **Focus Category:** | Water Quality, Agriculture, Groundwater |
| **Descriptors:** | microorganisms, polyacrylamides, recharge, infiltration, groundwater, vadose zone, virus, bacteria |
| **Lead Institute:** | University of Hawaii at Manoa |
| **Principal Investigators:** | Chittaranjan Ray, Roger S. Fujioka |

## Publication

1. Wong, Tiow Ping, 2001, Polyacrylamide (PAM) effects on viruses and bacteria transport in an unsaturated Oxisol, MS dissertation, Department of Civil Engineering, University of Hawaii at Manoa, Honolulu, Hawaii, 82 pp.
2. Teo, J., C. Ray, and S. El-Swaify, 2001, Polymer effects on soil erosion control reduction and water quality improvement for selected tropical soils, in J.C. Ascough II and J.C. Flanagan (ed.), Soil Erosion Research for the 21st Century, Proceedings of the International Symposium, held at Honolulu, Hawaii, Jan. 3-5, 2001, American Society of Agric. Engineers, St. Joseph, Mich., pp. 42-45.

## Problem and Research Objectives

High-molecular-weight anionic polymers are currently being used for soil erosion control in land under furrow irrigation and to a limited extent in land under sprinkler irrigation. It has been demonstrated that more than 95% of sediment loss in land under furrow irrigation can be prevented by using a high-molecular-weight polyacrylamide (PAM) at a concentration of 10 mg/l. Use of PAM also has significant potential to reduce soil loss at construction sites. During the erosion-control experiments, it was discovered that PAM use also enhances the water-infiltration capacity of soils. Enhanced infiltration in soils treated with wastewater or biosolids can have adverse health effects due to the rapid movement of pathogenic organisms through the soil to the groundwater. However, the effect of polymer addition on pathogen transport (from biosolids or wastewater) has not been investigated. Viruses are microscopic particles with surface charge, and they tend to adsorb to soil particles. By the same token, the anionic PAM also adsorbs to soil particles. Soil pH, clay and organic matter content, degree of water saturation, and other environmental and geologic factors are expected to impact the transport behavior of these pathogenic organisms.

The objectives of this research are to examine the transport of bacteria, bacteriophage, and possibly bacteria- and virus-sized microspheres in polymer-amended agricultural soils and to compare their transport behavior to control conditions under which no polymer or soil amendments are added.

## Methodology

The study involved an initial screening of polymers for their ability to reduce erosion and enhance infiltration in select Hawaii soils (Teo et al., 2001). Then, breakthrough experiments for bromide were conducted in packed sand columns under various degrees of saturation (Wong, 2001). Following that, field soils were obtained from agricultural land where potential exists for the application of wastewater and polymers. The soils were air dried, passed through a 4-mm sieve, and packed to field bulk densities. The packed columns were saturated with a leaching solution containing 0.01 molar $CaCl_2$. Column lengths varied from 10 to 22.5 cm. Application rates varied from 17.75 cm/d for 15-cm columns to 51.8 cm/d for 10-cm columns. The period of application also varied, depending on the length of simulation. Once steady-state flow conditions were established, bromide was injected instantaneously to the top of the column or applied continuously in the leaching solution. From the bromide breakthrough data, solute transport parameters were estimated from an inverse solution of the advection-dispersion equation. In subsequent experiments, a laboratory strain of *Escherichia coli*, sewage effluent, bacteriophage (MS-2), and enterococcus bacteria were added to the leaching solution. Initially, the organisms were added as a single pulse at the start of the experiment, and breakthrough was monitored as a function of time. The cell counts for bacteria ranged from 5 to 8 log orders, whereas that for the phage was on the order of 7 logs/ml of solution. The effluent was collected until 10+ pore volumes of leaching solution passed through the column. In all cases, the leachate samples were negative for bacteria or virus. In subsequent experiments, MS-2 phage and bacteria were injected continuously along with the leaching solution.

## Principal Findings and Significance

In a screening study involving four soils, it was found that the polymer worked well on all except one soil (a Vertisol) in terms of preventing soil loss and enhancing infiltration (Teo et al., 2001). For the Wahiawa Oxisol, nearly 98% of applied rainfall was directed as infiltration at a polymer dose of 10 kg/ha; this amount was more than 25% to 40% that for the control runs. It was clearly concluded that polymer amendment to Hawaii soils could enhance infiltration, and hence recharge.

Initial results of *E. coli* transport in sand columns indicated that there was significant retention of this bacteria in the sand. While the input concentration was on the order of 8 logs/ml (10 ml applied volume), the recovered bacteria at the bottom of a 15-cm sand column was only 2 log orders/ml after 2.7 pore volumes passed through the column. An analysis of sand samples from the column indicated that most of the bacteria were retained in the sand. (It was later discovered that the pH of silica sand [1:1 mixture of sand and water] was on the order of 4.5. It was learned that most manufacturers acid-wash the silica sand prior to shipping.) After the sand was thoroughly washed in pure water, its pH increased to 6.49. Repeating the experiment under the same conditions, we were able to detect a maximum 4 log bacteria/ml of leachate. The respective peaks of both bromide and bacteria occurred at the same time.

The Wahiawa Oxisol soil was used later for both bacteria and phage leaching experiments. A shorter (10-cm) length soil column was used to conduct initial runs. Bromide at a concentration of 5 mg/l and *E. coli* at $1.96 \times 10^7$ colony-forming units (CFU)/ml were spiked with the 0.01 molar $CaCl_2$ leaching solution and were continuously applied to the top of the soil column at a rate of 5 cm/h. The experiment continued until 6 pore volumes of water passed through the column. The peak concentration of bacteria in the leachate was less than 1 log order/ml. The bromide concentration reached its peak (original concentration) after 3.4 pore volumes of leaching solution passed through the column. It was unclear if the bacteria were from the bypass flow along the walls of the columns.

A second experiment was run under similar conditions but for a longer time. Approximately 20 pore volumes of leaching solution passed through the soil column. The feed concentration of *E. coli* ranged between $1.16 \times 10^7$ and $9.12 \times 10^6$ CFU/ml. Between 4.65 and 20 pore volumes, an average of 2.46 CFU of *E. coli*/ml of leachate was discovered, indicating tremendous retention in the soil. The sorbed bacteria concentration from samples collected from the soil column was on the order of $1.41 \times 10^7$ CFU/g of dry soil.

A bacteriophage, MS-2, was used in the third experiment. Except for the bulk density, the hydraulic conditions for the soil column remained the same. The bulk density of the soil was 0.99 g/cm$^3$ compared to that of 1.06 g/cm$^3$ for the previous two experiments. The experiment was run for 15 pore volumes. The bacteriophage stock solution had to be changed once during the experiment. The initial concentration of the phage was $5.30 \times 10^7$ plaque-forming units (PFU)/ml and that at the end of the experiment was $3.69 \times 10^6$ PFU/ml. No bacteriophage was detected throughout the experiment. The average phage adsorbed to the middle portion of the soil column was $1.06 \times 10^8$ PFU/g of dry soil, and that at the bottom portion of the soil column was $2.11 \times 10^5$ PFU/g.

A longer experiment using MS-2 bacteriophage was conducted. Even though this experiment was run long enough to pass 100 pore volumes of stock solution through a 10-cm soil column, no phage was found in the break-through solution. Since it is impractical to run such long experiments under unsaturated conditions involving both phage and bacteria (bacteria cannot survive such long periods of time), all further experiments were conducted in 15-cm columns involving 10 to 20 pore volumes of water. Each experiment contained a PAM-treated soil column and a control. At the conclusion of each experiment, the soil column was sliced into 2.5-cm layers, and the phage and bacteria were eluted from the soil.

In the PAM-treated columns, the MS-2 phage traveled to a depth of 12.5 cm after passing through 18 pore volumes of water containing more than 8 log orders of phage/ml of water. In the control columns, the penetration was only up to 7.5 cm. Percent recovery of phage was 5% from polymer-treated columns and 17.5% from control columns.

A similar experiment was conducted for *E. coli* in 15-cm columns for about 9 pore volumes of water containing over $10^8$ cells/ml of water. Bacterial cells were found to depths of 10 cm in control and PAM-treated columns, indicating no significant difference between the two treatments. However, elution tests showed that it is difficult to wash bacteria off from polymer-treated soils.

A separate experiment was conducted to determine the overall effect of surfactants on the migration of phage and *E. coli* in soil columns in control and PAM-treated columns. Nine pore volumes of bacteria and phage cells were added to the columns with over $10^8$ cells/ml. No phage was found in the leachate, but a small amount of *E. coli* was found after day 1. Analysis of soil samples from the column showed that the phage had migrated to a depth of 7.5 cm in PAM-treated columns and to a depth of 5 cm in control controls. *E. coli* was found at all depths in both the control and PAM-treated soil columns.

Adsorption tests were conducted to examine the maximum sorption capacity of Wahiawa soil for phage and *E. coli.* Problems were encountered in counting *E. coli* in supernatant since they were subject to settling during centrifugation. For phage, sorption was quick, as most of it took place in the first 30 minutes. There was no significant difference between the amount of sorption calculated for 45 minutes and for 4 hours. As for *E. coli*, sorption appeared to be slow, and there were some differences between the amount of cells counted at 30 minutes and at 4 hours, using the same speed of centrifugation.

A limited number of experiments were conducted using 0.75-µm-diameter and 0.05-µm-diameter fluorescent microspheres purchased from the Polysciences, Inc. (Warrington, Penn.) to simulate the transport of microbes in soil. The spectrofluorometer was able to detect microspheres only at high concentrations: $10^3$ spheres/ml in distilled water and $10^5$ spheres/ml in soil solutions containing $CaCl_2$. It is suspected that soil humic acids and other colloids may have contributed to raising the background level. Details of these experiments can be found in Wong (2001).

A detailed investigation of the soil properties indicated that the iron oxide content of Wahiawa soil is on the order of 18%. Further, the investigation revealed that the clay content of Wahiawa soil varies between 60% and 80%. It is suspected that unsaturated conditions with low pH, high iron oxide, and high clay content contribute to the significant retention of bacteria and phage in the soil column. Depth to water in central Oahu varies between 200 and 300 m in areas where wastewater is currently land-applied for landscape irrigation. The results of this study indicate that for the given conditions, the reuse of effluent in Hawaii would not have adverse impacts on groundwater.

## Basic Information

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|---|---|
| **Title:** | Assessment of Chemical Pollution and Bioavailability in Pearl Harbor Using Supercritical Fluid and Immunochemical Methods |
| **Project Number:** | C-06 |
| **Start Date:** | 9/30/1998 |
| **End Date:** | 2/28/2001 |
| **Research Category:** | Water Quality |
| **Focus Category:** | Methods, Water Quality, Sediments |
| **Descriptors:** | |
| **Lead Institute:** | University of Hawaii at Manoa |
| **Principal Investigators:** | Qing X. Li, Roger W. Babcock |

## Publication

1. Guo, Fengmao; Qing X. Li; and Jocelyn P. Alcantara-Licudine, 1999, Na4EDTA-assisted sub-/supercritical fluid extraction procedure for quantitative recovery of polar analytes in soil, Anal. Chem. 71(7):1309-1315. Li, Kai; Lee Ann Woodward; Alexander E. Karu; and Qing X. Li, 2000, Immunochemical detection of polycyclic aromatic aromatic hydrocarbons and 1-hydroxypyrene in water and sediment samples, Anal. Chim. Acta 419:1-8. Li, Qing X.; Eul-Chul Hwang; and Gengmao Guo; 2001, Occurrence of herbicides and their degradates in Hawaiis groundwater, Bull. Environ. Contam. Toxicol. 66:653-659.

## Problem and Research Objectives

Contaminated sediment is a serious problem in many watersheds in Hawaii, 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, Hawaii. 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 Hawaii 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 on 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-$CO_2$) 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).

An ELISA procedure that we developed is applied for the analysis of PAHs. In addition, an ELISA method is used to analyze groundwater samples for atrazine. This method was optimized so that it can detect about 0.1 ppb of atrazine in groundwater without sample preparation, making it very economical.

## Principal Findings and Significance

This project has yielded advanced methods for monitoring toxic pollutants in soils and sediments. This is of significance because toxic pollutants can cause adverse effects to the environment. For example, PAHs pose imminent danger to biological communities in the Hawaiian Island National Wildlife Refuge, among other places. A novel procedure was developed to recover these toxic chemicals from soils using supercritical carbon dioxide (Guo et al., 1999, *Anal. Chem.* 71:1309-1315). This extraction procedure was integrated with immunoassays to economically analyze PAHs in the sediments collected from national wildlife refuges on Oahu (Li et al., 2000, *Anal. Chim. Acta* 419:1-8).

An ELISA method was developed and used to screen for the presence of atrazine in 52 wells (Li et al., 2001, *Bull. Environ. Contam. Toxicol.* 66:653-659). 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 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.

Additionally, the bioavailability of the insecticide carbofuran was studied using a microbial assay (Microtox assay). Samples for the study were obtained from a carbofuran spill site on Laysan Island, French Frigate Shoals (David et al., 1999, paper presented at the 218th ACS national meeting, Aug. 22-26, 1999, New Orleans).

During the 12-month no-cost extension period through February 28, 2001, the investigators were involved in publication and technology transfer activities. A biotechnology workshop, sponsored by the State of Hawaii Millennium Workforce Development project, was conducted from November 27 to December 8, 2000. Mr. Joseph Lichwa of the University of Hawaii Water Resources Research Center attended the workshop and obtained training in a wide range of techniques, including the analytical procedures developed by investigators of this project.

**Articles in Refereed Scientific Journals**

Guo, Fengmao, Qing X. Li, and Jocelyn P. Alcantara-Licudine, 1999, $Na_4$EDTA-assisted sub-/supercritical fluid extraction procedure for quantitative recovery of polar analytes in soil, *Anal. Chem.* 71(7):1309-1315.

Li, Kai, Lee Ann Woodward, Alexander E. Karu, and Qing X. Li., 2000, Immunochemical detection of polycyclic aromatic hydrocarbons and 1-hydroxypyrene in water and sediment samples, *Anal. Chim. Acta* 419:1-8).

Li, Qing X., Eul-Chul Hwang, and Fengmao Guo, 2001, Occurrence of herbicides and their degradates in Hawaii's groundwater, *Bull. Environ. Contam. Toxicol*. 66:653:659.

## Basic Information

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| **Title:** | Predicting the Effectiveness of High-Intensity UV Lamp Technology as a Disinfectant for Various Quality Wastewaters Using the Collimated Beam Method (Phase II) |
| **Project Number:** | C-07 |
| **Start Date:** | 3/1/1999 |
| **End Date:** | 2/28/2001 |
| **Research Category:** | Water Quality |
| **Focus Category:** | Water Quality, Waste Water, Treatment |
| **Descriptors:** | water quality; low-pressure, low-intensity UV systems; medium-pressure, high-intensity UV systems, bacteriophages |
| **Lead Institute:** | University of Hawaii at Manoa |
| **Principal Investigators:** | Victor D. Moreland, Roger S. Fujioka |

## Publication

## Problem and Research Objectives

This synopsis covers only the second year of a two-year project.

The use of ultraviolet (UV) light as a disinfection method has recently become viable as an alternative to chlorine for the treatment of water and wastewater. Unlike chlorine, UV light does not result in the formation of carcinogenic or toxic by-products that can be released into the environment.

Most studies concerning the effectiveness of UV light as a disinfection method to inactivate waterborne pathogens have traditionally been based on low-pressure, low-intensity (LPLI) UV systems. LPLI UV systems produce a single wavelength of light (monochromatic) at 254 nm. UV light generated at 254 nm can prevent the replication of microorganisms by causing the formation of uracil (RNA) or thymine (DNA) dimers in their genome. Studies using LPLI beams (Meng and Gerba, 1996, *Wat. Res.* 30(11):2665-2668; Battigelli et al., 1993, *Wat. Sci. Tech.* 27(3-4):339-342) have been conducted to compare inactivation rates between different viruses and bacteria. The results of these studies have shown that bacteria are typically less resistant than viruses to UV irradiation (Moreno et al., 1997, *Wat. Sci. Tech.* 35(11-12):233-235; Tree et al., 1997, *Wat. Sci. Tech.* 35(11-12):227-232).

A more recent development in UV technology is the medium-pressure, high-intensity (MPHI) UV system which emits a polychromatic light with wavelengths ranging from 200 to 600 nm. Studies have shown that the MPHI system has an effective germicidal intensity that is four times greater than that attained with a single wavelength at 254 nm. However, information regarding the ability of the MPHI UV system to inactivate waterborne pathogens, such as viruses and bacteria, is limited.

Microorganisms such as fecal coliforms and enterococci are used as fecal indicators of water and wastewater quality. Another biological parameter used to determine the treatment efficiency of water and wastewater is the reduction in viral load. Viruses are unique in that they can differ structurally (icosahedral, tailed, rod shaped) as well as genetically (single- or double-stranded DNA, single- or double-stranded RNA). This study looked at the inactivation rates of various indicator bacteria and bacteriophages by both the LPLI and MPHI collimated beam UV systems. Bacteriophages were used as models for human enteric viruses because of their structural and genetic similarities to these viruses, ease of propagation, and safety due to their lack of virulence to a human host.

## Methodology

### Irradiation of Wastewater Samples by LPLI and MPHI Collimated Beam Units

Secondary treated wastewater was collected from various wastewater treatment facilities throughout Oahu. Treatment methods included trickling filter solids contact, trickling filter (plastic media), waste stabilization pond, conventional activated sludge, and extended activated sludge processes.

Fifty milliliters of the secondary treated effluent were placed into a 100-ml sterile crystalizing dish containing a micro stir bar to ensure proper mixing and even UV exposure. Samples were then irradiated with either the LPLI or MPHI collimated beam system at doses of 5, 10, 20, 30, 40, 50, and 75 mW s/cm$^2$. The dose was calculated according to the equation Dose = Intensity X Time, where the Intensity at 254 nm was determined using a radiometer (International Light, Inc.). UV transmittance (254 nm) was also measured for each wastewater sample using a photometer (Trojan Technologies, Inc.). After UV irradiation exposure, the samples were filtered through a 0.45-µm filter (Gelman GN-6), placed on appropriate bacteriological media, and incubated for 18 to 24 hours. The colony-forming units (CFUs) per 100 ml were then determined.

### Irradiation of Bacteriophages with the LPLI and MPHI Collimated Beam Units

A bacterial culture of *Escherichia coli* (piliated/ampicillin resistant) was grown for 18 to 24 hours in nutrient broth/0.5% NaCl containing 5X ampicillin. The overnight culture was then diluted (1:10) and allowed to incubate for an additional 2 hours at 37°C to attain growth in log phase. MS-2 was propagated with the prepared bacterial culture by mixing 0.1 ml of MS-2 + 0.1 ml of the *E. coli* host into 3 ml of top agar. The top agar consisted of nutrient broth/0.5% NaCl + 0.5% agar that was melted and maintained at 50°C prior to use. The MS-2/*E. coli* top agar mixture was then plated onto a bottom agar consisting of nutrient agar/0.5% NaCl + 5X ampicillin and incubated for 18 to 24 hours. The plaque-forming units (PFUs) were then determined.

Bacteriophages phi X-174, PRD-1, and T4 use bacterial host *E. coli* 13706 (ATCC), *Salmonella typhimurium*, and *E. coli* 11303 (ATCC), respectively. All host strains were grown in media containing nutrient broth + 0.5% NaCl and followed the basic propagation method as described above for MS-2.

Fifty milliliters of sterile PBS containing the bacteriophage (MS-2, PRD-1, phi X-174, or T4) at a concentration of $10^6$ to $10^7$ PFU/ml were placed into a 100-ml crystalizing dish. A sterile stir bar in the crystalizing dish allowed for adequate mixing and even exposure of the bacteriophage to the UV light. The sample was then irradiated at 5, 10, 20, 30, 40, 50, and 75 mW s/cm$^2$. After UV exposure, the bacteriophages were plated with its appropriate host and PFUs enumerated after an 18- to 24-hour incubation period. The susceptibility of each bacteriophage to both the LPLI and MPHI systems was then assessed.

## Principal Findings and Significance

### UV Irradiation of Various Wastewater Samples

Results indicate that for wastewater treated by activated sludge processes (at the Paalaakai and Waimanalo wastewater treatment plants), LPLI and MPHI UV collimated beam irradiation is capable of reducing the population of fecal coliforms and enterococci by 4 to 5 logs at a dose of 75 mW s/cm$^2$. Treatment facilities which used methods such as trickling filter solids contact for wastewater treatment (e.g., Honouliuli and Waianae wastewater treatment plants) showed a slightly more UV-resistant bacterial population. Bacterial reduction at facilities employing trickling filter solids contact technology showed a 4-log reduction in fecal coliform density and a 3.5-log reduction in enterococci populations at a dose of 75 mW s/cm$^2$. The greater resistance (greater log survival) to UV disinfection could be attributed to the protective effect offered by the presence of extracellular polymers produced by the microorganism in a trickling filter solids contact treatment system. Therefore, it can be concluded that the secondary treatment process used at each wastewater treatment facility has an influence on the effectiveness of both the LPLI and MPHI UV treatments in reducing certain bacterial populations.

### UV Irradiation of Bacteriophages

Results indicate that bacteriophages MS-2 (ssRNA) and PRD-1 (dsDNA) were the most resistant to UV disinfection when irradiated by both types of UV collimated beam systems. UV irradiation of MS-2 gave a 1-log reduction ($D_{90}$) at 25 mW s/cm$^2$, whereas UV irradiation of PRD-1 resulted in a 1-log reduction at 27 mW s/cm$^2$. In contrast, bacteriophage phi X-174 (ssDNA) was quite susceptible to UV irradiation, resulting in a 1-log reduction at 4.3 mW s/cm$^2$. Additionally, T4 (dsDNA) was the most susceptible to UV disinfection, resulting in a 1-log reduction at 1 mW s/cm$^2$. The resistance of MS-2 and PRD-1 can be attributed to genetic and structural factors such as the nucleic acid (MS-2 has an RNA genome) and lipid content (PRD-1 is a lipid phage) of these bacteriophages, although other resistance and/or susceptibility factors can also be considered.

This study revealed that for the MPHI system, wavelengths in addition to that which is emitted at 254 nm are responsible for bacterial and virus inactivation. Other factors such as the method used in secondary treatment of wastewater also have an effect on the removal of microorganisms subjected to UV disinfection. Furthermore, the attractiveness of using the MPHI system is that its effective germicidal intensity is approximately four times greater than that attained with a single wavelength at 254 nm. This means a shorter exposure time is needed to achieve a particular dose for the MPHI system as compared to the LPLI system. Therefore, it can be concluded that the MPHI UV system is appropriate for water and wastewater disinfection of bacteria and viruses.

# Information Transfer Program

Information Transfer Program

WRRC's information transfer program continued its major activities in this reporting period: organizing the Center's regular semi-monthly seminar series; publishing a newsletter, producing slides and poster materials for talks and project reports; responding to telephone and mail requests for water information, maintaining and updating the Center's web site, and making presentations to community groups. These activities have two main thrusts: first, to disseminate results of WRRC research; and second to put the Center and its researchers in a position to respond as new water-related problems emerge.

## Basic Information

| | |
|---|---|
| **Title:** | WRRC Website |
| **Start Date:** | 3/1/2000 |
| **End Date:** | 2/28/2001 |
| **Descriptors:** | |
| **Lead Institute:** | Water Resources Research Center |
| **Principal Investigators:** | Philip Moravcik |

## Publication

# WRRC Website: 2000-2001

Current and historical information needs to be made easily accessible to people and agencies interested in water issues and problems, as well as water topics in general. Anyone with access to the Web can easily search for information or publications at the WRRC website.

The technology transfer office continues to expand the Water Resources Research Center's internet presence at URL http://www2.hawaii.edu/wrrc/WRRC.html. The site describes the Center's origins, missions, activities, and faculty. Increasingly, WRRC publications are being posted on the site and hyperlinks are provided to reports or related information. Abstracts of WRRC publications are available at the website.

## Basic Information

| | |
|---|---|
| **Title:** | Water Database |
| **Start Date:** | 3/1/2000 |
| **End Date:** | 2/28/2001 |
| **Descriptors:** | |
| **Lead Institute:** | Water Resources Research Center |
| **Principal Investigators:** | Philip Moravcik |

## Publication

# WRRC Water Database  2000-2001

Water agencies and the public frequently call WRRC for information on water and wastewater issues. Articles appearing in the various newspapers published in the state are an important source of current and historical information. Pertinent articles are culled from Hawaii’s newspapers and maintained in a searchable database by the technology transfer office.

The technology transfer office maintains a database of local newspaper articles pertaining to issues of water and wastewater. This database is made available to individuals from within the university community as well as to government agencies, the private sector and the interested public.

# Basic Information

| | |
|---|---|
| **Title:** | WRRC Seminar Series |
| **Start Date:** | 3/1/2000 |
| **End Date:** | 2/28/2001 |
| **Descriptors:** | A semi-weekly series of seminars on water resources topics. |
| **Lead Institute:** | Water Resources Research Center |
| **Principal Investigators:** | Philip Moravcik |

# Publication

# 2000 WRRC Seminar Series

The Seminar Series is designed to foster communication amongst WRRC researchers, students, and the research audience of government officials, private sector personnel and members of the public interested in water resources. A WRRC faculty member is appointed each semester to draw up and invite a list of speakers. Topics vary depending on interests of the coordinator and availability of speakers. Typically, the seminars include reports of WRRC projects and discussions by government officials of emerging water-related problems.

## Spring Semester 2000 Seminar Coordinator: Dr. James Moncur

**Date Speaker's Name**
**Title of Seminar**

**3/2/00 Felix Limtiaco, James Yamamoto, Barry Usugawa**
Integrated Water Resources Planning for the Board of Water Supply

**3/16/00 Tim Johns**
Problems and Issues of the Commission on Water Resource Management

**4/6/00 John Klein**
The U.S. National Water Quality Monitoring Council: Monitoring Collaboration for Better Information

**5/3/00 Ronald Harvey**
Sub Surface Microbial Transport: The slow lane has become faster

**5/4/00 Keith Kawaoka**
Soil Sampling Study of the Village Park & West Loch Fairways Communities

**5/15/00 Ronald Linsky**
Critical Water Issues and Needs of the Future – "The Value of Water"

**5/15/00 Mark LeChevallier**
Critical Water Issues and Needs of the Future – "What's so Complicated About Water: It Falls From the Sky Doesn't it?"

**5/16/00 Mark LeChevallier**
Evaluation of the Cell Culture/PCR Method for the Detection of Infectious *Cryptosporidium parvum*

**6/15/00 Christine Shoemaker**
Optimization of Groundwater Remediation for Pump and Treat and Bioremediation Systems

## Fall Semester 2000 Seminar Coordinator: Dr. Roger Babcock

**8/24/00 Ken Windram**
Start up of the Honouliuli Water Recycling Plant

**10/4/00 Derek Mukai, Doug Yamamoto, Kyle Yukumoto**
R-1 Quality Reclaimed Water Production Facilities at Makena, Maui and Keahole, Hawaii

**10/12/00 Robert Smith**
Up a Creek without a Paddle: The East Honolulu Wastewater Treatment Plant Water Reuse Experience

**11/1/00 Rick Sakiji**
How California Experiences with Design and Operation of Ultraviolet Wastewater Disinfection Facilities lead to Revisions of the NWRI Disinfection Guidelines

**11/16/00 Leighton Lum, Lee Mansfield**

Upgrading the Historic Wahiawa WWTP to Improve Water Quality and Continue Reuse Into a Second Century

**12/5/00** **William Rogers**
Design and Start-up of the Dole Foods Wetland Wastewater Treatment Facility

## Spring Semester 2001 Seminar Coordinator: Dr. Aly El-Kadi

**1/18/01** **Adam Reinhardt**
Assessment of Nitrate Leaching in the Pearl Harbor Watershed and the Potential to Reduce it.

**2/1/01** **Diane Drigot**
Restoring Clean Water in Hawaii Following A Watershed Approach: Progress, Challenges, and Opportunities

**2/15/01** **Delwyn S. Oki**
Comparison of Analytical and Numerical Estimates of Ground-Water Level Declines Caused by Withdrawals, and Implications for Sustainable Yield in Hawaii

**2/28/01** **Terry C. Hazen**
Aerobic Enhancement of Landfill Remediation

## Basic Information

| | |
|---|---|
| **Title:** | WRRC Newsletters |
| **Start Date:** | 3/1/2000 |
| **End Date:** | 2/28/2001 |
| **Descriptors:** | |
| **Lead Institute:** | Water Resources Research Center |
| **Principal Investigators:** | Philip Moravcik |

## Publication

# WRRC Newsletter and Project Bulletin

Researchers need channels of communication to potential users of their results. WRRC needs a means of publicizing its project results and other activities. Newsletters and project bulletins are designed to convey this information in an informal manner.

Two newsletter issues were produced during the reporting period. The newsletter issues describe results of WRRIP and other WRRC research; announce forthcoming conferences, presentations by visiting speakers, and other WRRC activities; and convey news of faculty and other researchers. They also include essays on water-related issues in the state. 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. Nearly one thousand copies were distributed.

**Other Publications**

Water Resources Research Center Bulletin, August 2000, Water Resources Research Center, University of Hawaii at Manoa, Honolulu, Hawaii, 8 pp. Water Resources Research Center Bulletin, December 2000, Water Resources Research Center, University of Hawaii at Manoa, Honolulu, Hawaii, 6 pp.

# USGS Summer Intern Program

# Student Support

None

# Notable Awards and Achievements

None

# Publications from Prior Projects

1. Liu, Clark C.K., 2000, Linear systems approach to subsurface pollutant transport analysis, in "Proceedings of the Fourteenth Engineering Mechanics Conference," American Society of Civil Engineers, May 21-24, 1000, Austin, Texas (published on CD-ROM)