Water Resources Research Center

Annual Technical Report

FY 1999

Introduction

The period covered by this report has seen several changes at the University of Hawaii Water Resources Research Center. First, Director Roger S. Fujioka decided to return to full-time research. Assistant Director James Moncur was appointed director as of August 1999. WRRC has continued wrestling with budgetary problems originating in the state's stagnant economy and resultant University austerity. Thus, efforts to augment congressional funding for the WRRIP program have become ever more significant. WRRIP funding, though small in size, and though shrunk to less than half the 1980 levels in real, inflation-adjusted terms, offer flexibility not available with other funds. On a more positive note, however, the Center has University approval to fill one position that has been vacant since 1995. This position will be a joint appointment with an instructional department. A number of research proposals are under evaluation, and we hope to substantially increase resources available through this route. As of March 31, WRRC had, in addition to Director's Office and Technology Transfer projects, four active WRRIP section 104(b) grants: • Aly I. El-Kadi and Francoise M. Robert, "In situ experimental analysis and modeling of diesel fuel bioremediation in a tidally influenced aquifer." Begun in 1997, regulatory hurdles related to drilling wells delayed fieldwork for this project. However, additional funding was obtained from the Hawaii Department of Transportation. Drilling began in May 1999 and the project is proceeding as planned. • Qing X. Li and Roger W. Babcock, Jr., "Assessment of chemical pollution and bioavailability in Pearl Harbor using supercritical fluid immunochemical methods." This project has generated advanced methods for monitoring toxic pollutants in soils and sediments, that is, methods that are simpler and generate less solvent waste than conventional procedures. • Chittaranjan Ray, Samir A. El-Swaify, and Bunnie S. Yoneyama, "Polymer effects on virus and bacteria transport in subsurface." Certain polymers have proven useful in controlling soil erosion and, in the process, enhancing aquifer recharge. This project deals with a potential side effect: in soils irrigated with wastewater, the enhanced aquifer recharge may also enhance the flow of pollutants into potable aquifers. Investigators are looking into conditions in which this problem occurs and can be overcome. • Victor Moreland and Hans-Jurgen Krock, "Predicting the effectiveness of high-intensity UV lamp technology as disinfectant for various quality wastewaters using the collimated beam method." Investigators in this project aim to create a procedure to predict whether a given wastewater can be effectively disinfected by low- and high-intensity UV light. In addition, Geology and Geophysics Professor Eric De Carlo has in progress a section 104(g) grant, "Elucidation of sources of suspended solids and anthropogenically derived heavy metals in streams of small subtropical waters, Oahu, Hawaii." This project will identify sources of heavy metals in "water quality limited segments" of Hawaii surface waters and should help determine whether these problems stem from urban development or from natural erosion. It will also provide a basis for determining potential impacts of these nonpoint source pollutants on reef ecosystems. Other WRRC projects continue to examine and refine results of earlier WRRIP grants. Dr. Roger Fujioka, for example, has studied water quality problems associated with rebuilding an old seawater swimming pool on a beach near Waikiki, extending the results of several WRRIP projects going back nearly two decades. Professor Clark Liu has built and operated a prototype wind-powered desalination system with promising results. This project continues WRRIP-supported desalination research begun in the early 1990s. Technology transfer projects included a seminar series and two new issues of the WRRC newsletter, several project bulletins, and a new WRRC brochure. The technology transfer office also provided

major logistical support for the 1999 annual meeting of the Universities Council on Water Resources, held in Kamuela, Hawaii, in addition to preparing slideshows and conference poster presentations for WRRC projects. Beyond the WRRIP activities per se, many of Hawaii's basic water problems provide subjects of interest to WRRC researchers. Contamination of water supplies--surface and ground sources, as used for drinking, recreational, and commercial purposes--continues to be a major research focus of the Center. With other funding sources, WRRC pursues water problems of particular concern to Hawaii and other tropical areas, such as the quality of water supplied by rainwater catchment systems, treatment and reuse of wastewater, and preservation of recreational water quality. Biological means of remediating polluted water and soil sites, many resulting from long military use of these sites, is an emerging focus. A group of UH researchers continue their involvement in monitoring the biological and sediment impacts of Honolulu's disposal of advanced primary-treated effluent in deep ocean waters off the coast of Oahu. Others study the water quality effects of operating native Hawaiian fishponds.

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	02/29/2000
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	Associate Professor	University of Hawaii at Manoa	01
Francoise M. Robert	Assistant Professor	University of Hawaii at Manoa	02

Problem and Research Objectives

This project deals with the problem of contamination of subsurface nearshore sites in Oahu, Hawaii. 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 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 square areas (10 feet x 10 feet), which appeared to be similarly contaminated according to the most recent survey, were delineated at the study site. One monitoring well was drilled to 13 feet in the center of each area. One area (A) was treated with air and nutrients (ammonium nitrate only because phosphorus was in excess of the intended C:N:P ratio of 100:4:1). The second area (B) was treated with air only. The third area (C) was used as a control under normal conditions (no-action site). An air compressor delivered air at low pressure (3 to 5 psi) 12 hours/day via a hose and diffuser located at a depth of 12 feet in monitoring wells A and B. The loss of nutrients to the surrounding water was monitored by sampling the water through existing wells downstream of the treated site. The level of oxygen in the water was monitored with an oxygen probe via the monitoring wells at the control and treated sites and a well in a noncontaminated area (background level). To determine the progress of bioremediation, core samples from the tidal zone (which extends approximately from 6 to 8 feet below the ground surface) and from a 2-foot zone under it were drilled mechanically by a private company. Six soil samples were obtained on day 0 (06/23/99), day 117 (10/18/99), and day 299 (4/17/00) from the tidal zone in each of the three experimental areas. Due to physical hindrance, not all the samples from the 8- to 10-foot zone could be obtained. A fourth sampling is scheduled to take place in July 2000. At each sampling time the respective concentrations of total petroleum hydrocarbons (TPHs) and polycyclic aromatic hydrocarbons (PAHs) were determined by gas chromatography and immunoassay, respectively. The levels of total bacteria were determined by fluorescence microscopy (acridine orange counts) and by plate counts on R2A medium. Phenanthrene-degrading bacteria were enumerated by double-layer plate count. Diesel and pristane-degrading microorganisms were enumerated in multiwell plates by the most-probable-number technique. Modeling fate and transport of dissolved and free product in nearshore environments is complicated due to the physical, chemical, and biological processes involved. Numerical solutions are hindered by the nonlinear nature of the governing equations. This research will focus on the development of a field-scale model for biodegradation in a nearshore aquifer. Numerical difficulties limit the usefulness of available models to simulate the flow of the free product under tidal conditions. We will modify some of these to overcome such difficulties. 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

Due to difficulties in contracting the field work and securing an entry right to the site, the field work did not begin until May 1999. Thus, we could only do two of the four planned samplings by the time the extension for this project came to an end on February 29, 1999. However, we were able to obtain additional financial support ($50,000) from the owner of the site, the Hawaii Department of Transportation (Airports Division). The contract with the Hawaii DOT, valid until April 2001, will enable us to perform all four planned samplings. Experimental Results A complete interpretation of the data is not possible at this stage because we just performed the third sampling (day 299 = 4/17/00). However, the major findings to date are as follows. Without aeration, the level of dissolved oxygen (DO) in the tidal zone of the three areas is very low (2 mg/l or less in well water). With aeration, the level of DO is near 7.4 mg/l of water, the maximum at 0.5% salinity and a temperature of 280 to 300C. Gas chromatograms revealed that the diesel fuel contaminant is highly weathered (all n-alkanes are gone). The proportion of PAHs in the contaminant was elevated (9% to 12%) in comparison to the situation in fresh local No. 2 diesel (2%). The level of contamination in soil was less than anticipated from the surveys of free product which were used as a basis for the design of the study. Partial data for TPH on day 299 suggest a poor correlation between the level of free product in well water and the level of contaminant smeared in the tidal zone soil. Also, the level of contaminant was not uniform throughout the three areas studied. Well A was more contaminated than well B, whereas well C was hardly contaminated. A high variability in the distribution of the product was found within a given square area at each sampling time (e.g., the range of TPH in the tidal zone of area A on day 117 was 751 to 2,629 mg/kg of soil). The level of free product in well A fluctuated with time and with the addition of nutrients. For the first six months, it alternated between 0 and 0.5 cm. Since December 1999, well A has been contaminated with at least 6 cm of free product. We are looking into the possibility of a seasonal pattern in the movement of the free product, which may be governed by the equinoxial tides. Microbial enumerations in the tidal zone soil of square A on day 117 (second sampling) indicated a 3, 2, and 1 log unit increase in the counts of heterotrophic bacteria, phenanthrene-degrading bacteria, and both diesel and pristane degraders, respectively. No stimulation was observed in the tidal-zone soil of square B after addition of air only. Modeling We developed a field-scale model for hydrocarbon biodegradation, which is suitable for nearshore conditions. The main assumptions in the model include neglecting density effects, adopting a macroscopic approach for modeling bacterial activity, ignoring bacterial transport, and overlooking possible air effects on the validity of the bacterial growth model. Using an average value for density can put some limitation on the model. However, including density variations can put a limitation on the efficiency of the model and its suitability for field application. We also ignore the dissolution process preceding the degradation of a trapped product. The model solves the convection/dispersion equation for various species, each with the appropriate source/sink term. The source/sink terms reflect consumption/generation of species due to bacterial activities. The heat transport equation is also solved, but temperature values are only used to estimate the bacterial-inhibition factors. The model can simulate biotransformation reactions for any combination of electron donors and acceptors. Simultaneous multiple degradation processes and microbial populations can be simulated. The model includes expressions for inhibition due to unsaturated, heat, and pH effects. Although empirical in nature, these expressions or similar ones can be useful, especially considering the field-scale nature of the model. Parameters of these equations should be estimated by fitting the expressions to available data. The model is verified through comparison to analytical solutions for a single solute with linear sorption, and zero and first-order decay. Excellent match between numerical and analytical solutions was obtained for all cases simulated. The model was also successfully tested against laboratory data

that deals with toluene and benzene transport and biodegradation in a continuous-flow, water-saturated soil column. Effects of cyclic flooding and drainage of soils were also studied. Although the degradation process is expected to be site-specific, the model demonstrates that cyclic flooding and drainage are likely to negatively affect the efficiency of degradation. Constant water saturation near its optimal value is recommended for best results. Results of investigations at a hypothetical field site that examine the effects of cycles of soil wetting and drying associated with tides are also presented. We also applied the model to a typical field application, and we examined the effects of tides, saturation, and heat inhibition. The analysis demonstrates that inhibition due to the absence of optimal environmental conditions can have profound effects on the biodegradation process. Professional presentations El-Kadi, A.I., and F.M. Robert, 1998, A field-scale model for aerobic residual hydrocarbon biodegradation in unconfined aquifers under tidal conditions, presented at the meeting of the American Geophysical Union, San Francisco, December 6-10. El-Kadi, A.I., 2000, Modeling biodegradation of hydrocarbons in tidal aquifers, presented at PERC, Pacific Env. Restoration Conference, Honolulu, Hawaii, April 4-7.

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	Assessment of Chemical Pollution and Bioavailability in Pearl Harbor Using Supercritical Fluid and Immunochemical Methods
Project Number	C-06
Start Date	09/30/1998
End Date	09/29/2000
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	Professional Staff	University of Hawaii at Manoa	01
Roger W. Babcock	Assistant Professor	University of Hawaii at Manoa	02

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-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). 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. These assays will be adopted for the analysis of pollutants in saltwater and harbor sediments. We propose to conduct a pilot test to see whether the SFE and ELISA methods are feasible for bioavailability studies. 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 coastal areas in Hawaii and elsewhere.

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). 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). 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 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. Currently, the bioavailability of organic pollutants in Pearl Harbor sediments is being studied by a graduate assistant.

Descriptors

bioavailability, monitoring, pesticides, PAH, ELISA, supercritical fluid extraction

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. Li, K., L. Woodward, A.E. Karu, and Q.X. Li, 2000, Immunochemical detection of polycyclic aromatic hydrocarbons in National Wildlife Refuge in Oahu, Hawaii, Anal. Chim. Acta, in press.

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Polymer Effects on Virus and Bacteria Transport in Subsurface
Project Number	C-08
Start Date	03/01/1999
End Date	08/31/2000
Research Category	Not Applicable
Focus Category #1	Water Quality
Focus Category #2	Agriculture
Focus Category #3	Groundwater
Lead Institution	University of Hawaii at Manoa

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Chittaranjan Ray	Assistant Professor	University of Hawaii at Manoa	01
Samir A. El-Swaify	Professor	University of Hawaii at Manoa	02
Bunnie S. Yoneyama	Research Associate	University of Hawaii at Manoa	03

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 selected Hawaii soils. Then, breakthrough experiments for bromide were conducted in packed sand columns under various degrees of saturation. 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 CaCl2. Column lengths varied from 10 to 22.5 cm. The application rate was 5 cm/h (similar to that for an intense storm); however, the period of application 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, where as 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, either MS-2 phage or bacteria were injected continuously along with the leaching solution. Leaching continued until at least 20 pore volumes of solution passed through the soil column.

Principal Findings and Significance

In a screening study involving four soils, it was found that with the exception of one soil (a Vertisol), the polymer worked well in terms of preventing soil loss and enhancing infiltration. 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 (Teo et al. 2000, 2001). 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 within 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 bacteria were retained within 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 (4-inch) length soil column was used to accomplish this task. Bromide at a concentration of 5 mg/l and E. coli at 1.96 x 107 colony-forming units (CFU)/ml were spiked with the 0.01 molar CaCl2 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. 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 x 107 and 9.12 x 106 CFU/ml. Between 4.65 and 20 pore volumes, an average of 2.46 CFU of E. coli/ml of leachate was discovered. The sorbed bacteria concentration from samples collected from the soil column was on the order of 1.41 x 107 CFU/g of dry soil. A bacteriophage, MS-2, was used in the third experiment. The hydraulic conditions for the soil column remained the same except for the bulk density of the soil column. The bulk density of the soil was 0.99 g/cm3 compared to that of 1.06 g/cm3 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 x 107 plaque-forming units (PFU)/ml and that at the end of the experiment was 3.69 x 106 PFU/ml. No bacteriophage was detected throughout the experiment. The average phage adsorbed to the middle portion of the soil column was 1.06 x 108 PFU/g of dry soil, and that at the bottom portion of the soil column was 2.11 x 105 PFU/g. A longer experiment using MS-2 bacteriophage is being conducted at present. This experiment will run until 100 pore volumes of stock solution has passed through a 4-inch soil column. If breakthrough is obtained, PAM and lime (as an additive to soil) will be applied to the soil column in the next experiment, and the experiment will be repeated. The same experiment will be repeated for bacteria and microspheres. A detailed investigation of the soil properties indicated that the iron oxide content of the soil is on the order of 18%. Further, the clay content is on the order of 50%. Unsaturated conditions with low pH as well as high iron and clay content helped attenuation of the bacteria and phage in the soil column. If the longer test does not produce reasonable breakthrough, alternate means to expedite the production of breakthrough will be examined. This also would indicate that for the given conditions, the reuse of effluent in Hawaii would not have adverse impacts on the groundwater. References cited Teo, J., C. Ray, and S. El-Swaify, 2000, Effects of high molecular weight polymers on erosion reduction and infiltration enhancement in selected Hawaiian soils, being submitted to J. Soil Science (May 2000). Teo, J., C. Ray, and S. El-Swaify, 2001, A screening study of high molecular weight polymers in selected Hawaii soils for erosion reduction and infiltration enhancement, to be presented at the International Erosion Control Conference, Honolulu, Hawaii, January 3-5, 2001.

Descriptors

microorganisms, polyacrylamides, recharge, infiltration, groundwater, vadose zone, virus, bacteria

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

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Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Predicting the Effectiveness of High-Intensity UV Lamp Technology as a Disinfectant for Various Quality Wastewaters Using the Collimated Beam Method
Project Number	C-07
Start Date	03/01/1999
End Date	02/29/2000
Research Category	Water Quality
Focus Category #1	Water Quality
Focus Category #2	None
Focus Category #3	None
Lead Institution	University of Hawaii at Manoa

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Victor D. Moreland	Research Associate	University of Hawaii at Manoa	01
Hans-Jurgen Krock	Professor	University of Hawaii at Manoa	02

Problem and Research Objectives

Sewage and other forms of wastewaters (such as those resulting from aquaculture and animal production) have traditionally been considered undesirable products of society. To protect the environment and the public health, federal regulations require the treatment of wastewater to remove the organic content and disinfection to kill pathogenic organisms (e.g., bacteria, protozoans, and viruses) before it can be discharged into the environment or reclaimed for beneficial uses. Chlorine, the historical disinfectant of choice, is now discouraged because of its hazardous nature and because its use has been shown to be detrimental to the health of humans and aquatic organisms. A relatively new disinfectant process that does not have the problems associated with chlorine is ultraviolet (UV) radiation. UV technology as an effective disinfectant is based on a new lamp configuration within the disinfection unit. Unfortunately, UV systems built by different manufacturers are not equally effective. Moreover, there are some disadvantages in the use of UV systems, including high costs, photoreactivation, interfering factors in water (e.g., turbidity, suspended solids, absorbing compounds), uncertainties in measuring the UV dose, and the lack of residuals to be measured to monitor the system’s effectiveness. Thus, more information is required before predictions can be made

about the effectiveness of UV technology in disinfecting various types of wastewaters. The research objectives for Phase I and Phase II are (1) to determine the differences in the effectiveness of high-intensity and low-intensity UV lamps in terms of their ability to disinfect different classes of microorganisms found in wastewaters; (2) to determine the contributing effect of different radiation wavelengths on the disinfection of different microorganisms; (3) to determine how the quality of wastewater impacts the effectiveness of microorganism disinfection using high-intensity and low-intensity UV light; and (4) to use the results of the collimated beam tests to predict the effectiveness of high-intensity UV lamp technology in disinfecting different types of wastewater. For Phase II, an additional objective is to address UV disinfection of emerging new pathogens, especially different kinds of viruses. The study aims to provide a procedure to predict whether any wastewater can be effectively disinfected by low-intensity or high-intensity UV light technology.

Methodology

This study uses the collimated beam method to evaluate the effectiveness of polychromatic (many UV wavelengths) high-intensity UV light as a disinfectant by comparing its effectiveness with that of traditional monochromatic (single wavelength, 254 nanometers) low-intensity UV light. Disinfection is carried out on various classes of microorganisms in various quality wastewaters. Several organisms are analyzed for inactivation rates, and several physical water quality parameters are monitored. Because the collimated beam method is the only method that can truly measure UV dose, it allows for reproducible doses and its effect can be determined on wastewaters of various quality. Different wavelengths are tested for their role in the disinfection of different types of microorganisms with different resistance to UV disinfection. The microorganisms in the study include the traditional fecal bacterial indicators (enterococci, fecal coliform), a spore-forming bacteria (Clostridium perfringens), and a virus (FRNA bacteriophage). These microorganisms are structurally and genetically different and represent groups that have various sensitivities and resistance to UV disinfection.

Principal Findings and Significance

The effectiveness of the collimated beam method on several secondary effluents and filtered secondary effluents was evaluated. The results show that the secondary processes (suspended-growth versus attached-growth) produce different results on the microbial populations. Values obtained for the inactivation rates (k) and 90% reductions (D90) or one log reductions are shown for suspended-growth (activated sludge processes and stabilization ponds), attached-growth (trickling filters), and combined processes (trickling filter aerated solids contact, TFSC) in the following table. Enterococci and Fecal Coliform k and D90 Values for Various Secondary Treatment Processes ---------- ---------- Secondary Treatment Enterococci Fecal Coliform Process k D90 k D90 ---------- Activated sludge 0.28 8.3 0.55 4.2 Trickling filter 0.25 9.2 0.43 5.4 TFSC 0.29 8.1 0.53 4.4 Stabilization pond 0.34 6.7 0.60 3.8 ---------- As can be seen in the table, the results differ by organism for the various secondary treatment processes. The attached-growth process has the lowest k value for both the gram-positive (enterococci) and gram-negative (fecal coliform) organisms. Therefore, the D90 values are higher as shown in the table. It should be noted that the enterococci are more resistant than the fecal coliform for all secondary treatment processes. Secondary treatment processes typically have two classifications of microbial organisms: (1) free-organisms (nonparticulte-associated organisms) and (2) particulate-associated organisms. The above tabular data are from the free-organism dose-response curves for the various treatment processes. If we were to rank the treatment processes by the apparent resistance of the effluent microbes from least resistant to most resistant, it would be as follows: stabilization pond < activated sludge ~ TFSC < trickling filter.

Descriptors

water quality, ultraviolet disinfection, collimated beam, high-intensity UV, fecal indicators, spores, virus

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

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 Project Information

Basic Project Information	
Category	**Data**
Title	WRRC Seminar Series
Description	A semi-weekly series of seminars on water resources topics.
Start Date	03/01/1999
End Date	02/28/2000
Type	Conferences
Lead Institution	Water Resources Research Center

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Philip S. Moravcik	Professional Staff	Water Resources Research Center	01

Problem and Research Objectives

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.

Methodology

Principal Findings and Significance

Spring Semester 1999 Seminar Coordinator: Dr. Chittaranjan Ray, Department of Civil Engineering 03/04/99 Pierre Tierra, "Chemical Contamination at Pearl Harbor Naval Complex" 03/18/99 Molly Kihara, "The Ala Wai Dredging Conceptual Design and Environmental Assessment Project" 04/01/99 Elizabeth Flint, "Midway Atoll-Turning a Military Installation into a National Wildlife Refuge" 04/22/99 Delwyn Oki, "U.S. Geological Survey Ground-Water Modeling Studies in Hawaii" 05/04/99 Pierre Payment, "Is Drinking Water Microbiologically Safe in North America? Results of Prospective Epidemiological Studies in Canada" 05/06/99 Davis Bernstein, "Hawaii Voluntary Hazardous Substance Cleanup Program and the Federal Brownfields Redevelopment Initiative" Fall Semester 1999 Seminar Coordinator: Dr. Roger Fujioka, WRRC/School of Public Health and Department of Microbiology 09/09/99 Wiepko Terpstra,"Leptospirosis at the Turn of the Millenium: Still a Need for Better Diagnostic Tools" 09/23/99 Steve Parabicoli, "Hawaii Water Reuse Public Education Outreach Program" 10/07/99 Carol Ferguson, "The Waiahole Ditch Case: Lessons for Island Water Management" 10/15/99 Joseph Rouse, "Effects of Twin-Head Anionic Surfactants on Biodegradation of Polycyclic Aromatic Hydrocarbons in Aqueous and Soil Systems" 11/04/99 Victor Moreland, "Primary Effluent: Chlorine or UV Radiation Disinfection?" 11/18/99 Gary Gill, "An Overview of the Department of Health's Activities in the State" 12/02/99 David Craddick, "Mixing Surface Water and Groundwater" Spring Semester 2000 Seminar Coordinator: Dr. James Moncur, WRRC/Department of Economics 1/20/00 Jim Roumasset, "Economics of Oahu Water Management and Watershed Valuation" 2/3/00 Clark Liu, "Development and Testing of a Wind-Powered Reverse Osmosis Desalination System" 2/17/00 Richard Swartz, "Benthic Communities Near the Barbers Point Ocean Outfall, Oahu, Hawaii" 2/24/00 Terry Walker, "Risk Assessment 101"

Articles in Refereed Scientific Journals

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Basic Project Information

Basic Project Information	
Category	**Data**
Title	WRRC Website
Description	Expanding Website Pages Featuring WRRC and Its Activities
Start Date	03/01/1999
End Date	02/29/2000
Type	Publications
Lead Institution	University of Hawaii at Manoa

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Philip S. Moravcik	Professional Staff	Water Resources Research Center	01

Problem and Research Objectives

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.

Methodology

Principal Findings and Significance

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 now available at the website. 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 web pages in support of this function as well.

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Newsletter and Project Bulletin
Description	Informal user-oriented reports on WRRC research projects and activities
Start Date	03/01/1999
End Date	02/28/2000
Type	Newsletter
Lead Institution	Water Resources Research Center

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Philip S. Moravcik	Professional Staff	Water Resources Research Center	01

Problem and Research Objectives

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.

Methodology

Principal Findings and Significance

Two newsletter issues were produced during the reporting period, in addition to a bulletin outlining the results of a longstanding WRRC project. 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.

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Water Resources Research Center Bulletin, n.d., Water Resources Research Center, University of Hawaii at Manoa, Honolulu, Hawaii, 8 pp. Water Resources Research Center Bulletin, November 1999, Water Resources Research Center, University of Hawaii at Manoa, Honolulu, Hawaii, 6 pp. Ten Years of Biological Monitoring, February 2000, Water Resources Research Center, Honolulu, Hawaii, 12 pp.

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Water Database
Description	Maintaining Database of Local Newspaper Articles on Water and Wastewater Issues
Start Date	03/01/1999
End Date	02/29/2000
Type	Library And Database Services
Lead Institution	University of Hawaii at Manoa

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Philip S. Moravcik	Professional Staff	Water Resources Research Center	01

Problem and Research Objectives

Water agencies and the public frequently call WRRC for information on water and wastewater issues. One source of such information is the local newspaper. A database of articles culled from the newspaper is maintained by the technology transfer office.

Methodology

Principal Findings and Significance

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.

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

USGS Internship Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	1	4	N/A	N/A	5
Masters	N/A	6	N/A	N/A	6
Ph.D.	N/A	2	N/A	N/A	2
Post-Doc.	N/A	1	N/A	N/A	1
Total	1	13	N/A	N/A	14

Awards & Achievements

Publications from Prior Projects

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. Yang, P.Y., and Zhiyu, Wang, 1999, Integrating an intermittent aerator in a swine wastewater treatment system for land-limited conditions, Bioresource Technology 69:191-198.

Book Chapters

Dissertations

Water Resources Research Institute Reports

Fujioka, Roger S., director, 1999, Hawai'i Water Resources Research Center Annual Program Report for 1998-99, Water Resources Research Center, University of Hawaii at Manoa, Honolulu, Hawaii, 26 pages.

Conference Proceedings

David, M., S.Campbell, L.A. Woodward, and Q.X. Li, 1999, Characterization of a carbofuran spill site on a remote island of the Hawaiian Islands national Wildlife Refuge (abstract no. AGRO-93), 218th ACS national meeting, August 22-26, 1999, New Orleans, Louisiana, USA.

Other Publications