

Water Resources Research Center

Annual Technical Report

FY 2005

Introduction

Over the period covered by this annual report, UH WRRIC had six WRRIP 104b projects in various stages of completion, in addition to one 104g project and a USGS-sponsored internship. Also, there were two projects funded via USGS by the U.S. Army, five funded directly by other federal agencies, and nine by Hawaii state agencies, three by the City & County of Honolulu. One project was funded by a U.S. territory and seven projects by private firms.

These projects involved disciplinary expertise from engineering, geology, economics, botany, oceanography and ecology as well as part-time appointees from the private sector. WRRIC seminars and workshops brought together faculty from many other university departments as well as personnel of city, state and federal agencies. WRRIC also co-sponsored an American Water Resources Association Specialty Conference held in Honolulu in June 2005.

Looking to the future, the hurricanes of fall 2005 on the U.S. mainland, coupled with a relatively minor but still very damaging flood that hit the University of Hawaii at Manoa in October 2004, raised awareness of water-related hazards. WRRIC organized a community seminar in February 2005 dealing with the local flood and dedicated our regular fall 2005 seminars to a series of technical presentations examining rainfall and flood-related water management issues. The extraordinarily high rainfalls of February and March 2006 in Hawaii further emphasized these issues by, among other problems, causing a dam failure on Kauai (killing seven people) and contributing to a sewer line break in Waikiki that contaminated beaches in the states prime tourist destination. These issues remain of high importance in setting future research and information transfer agendas.

At the same time, population and economic pressures on water demand continued to pose long term questions regarding water quantity, quality and allocation issues, not to mention conservation and demand management. Recreational water quality, wastewater treatment and reuse remain high public profile issues presenting many technical problems.

Research Program

USGS WRRIP funding for FY2005 allowed the funding of four new 104b research projects, the first year (of three) of a 104g project and completion of a USGS-funded student internship. The 104b projects covered the subjects of helium as a groundwater tracer; membrane fouling; ecohydrology of alien vegetation; and economic modeling for integrated water source management. The 104g project joins hydrological and economic modeling in studying coastal groundwater management. The internship allowed a hydrology student to participate in a USGS study of a stressed aquifer on Maui.

Development of a New Technique for the Use of Dissolved Helium as an Environmental Groundwater Tracer

Basic Information

Title:	Development of a New Technique for the Use of Dissolved Helium as an Environmental Groundwater Tracer
Project Number:	2004HI55B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	Hawaii 1st
Research Category:	Ground-water Flow and Transport
Focus Category:	Hydrology, Solute Transport, Models
Descriptors:	Tracer Tests, Helium
Principal Investigators:	Aly I El-Kadi

Publication

Problem and Research Objectives

Tracer tests are an important method for determining the flow characteristics and patterns of subsurface water (such as groundwater aquifers) and surface water bodies (such as streams and the ocean). In such tests, a constituent is added to the water. The constituent is either non-native to that water or high enough in concentration to be distinguished from the native component in that water. Many of the commonly used tracers have one or more limitations, such as being toxic, being esthetically objectionable, being difficult to be differentiated from the naturally occurring fraction, requiring complex laboratory analysis for their detection and quantification, requiring a high concentration, and reacting with the aquifer matrix. These limitations are not common to helium, however. Thus, if a field method can be developed to detect and quantify the concentration of dissolved helium in surface or groundwater in real time, then helium has great potential for use in certain tracer applications, including its use near drinking water sources or in environmentally sensitive areas such as wetlands and fish farms, its use in areas where esthetics are a concern (e.g., recreational beaches), and its use in conjunction with investigations of the diffusion characteristics of groundwater aquifers.

Helium was successfully tested as a reliable and economical tracer (S.K. Gupta, L.S. Lau, P.S. Moravcik, and A.I. El-Kadi, 1991, *Injected Helium: A New Hydrological Tracer*, Special Report 06.01.90, Water Resources Research Center, University of Hawaii at Manoa, 94 pp.; L.S. Lau, and P.S. Moravcik, 1994, *Ground-water tracing with injected helium*, *Ground Water* 32(1):96–102). Its behavior in open tanks was identical to that of fluorescein dye. Although the system was simple and specific for helium, the small surface area and fragility of the thin quartz window limited its sensitivity and reliability. Moreover, the technique was only suitable for the analysis of discrete samples.

The objective of this project is to develop and demonstrate a new analytical system that substantially improves the precision and utility of the helium tracer for routine use in surface water and groundwater. The work proposed encompasses developing and calibrating the system, and testing the helium tracer in the laboratory against a commonly used tracer.

Methodology

Instrumentation

The new system consists of a gas extraction system and a separate helium analyzer (Figure 1). The design allows on-site, continuous, real-time monitoring in a completely automated structure. The results of the analysis are automatically recorded on a lap-top computer.

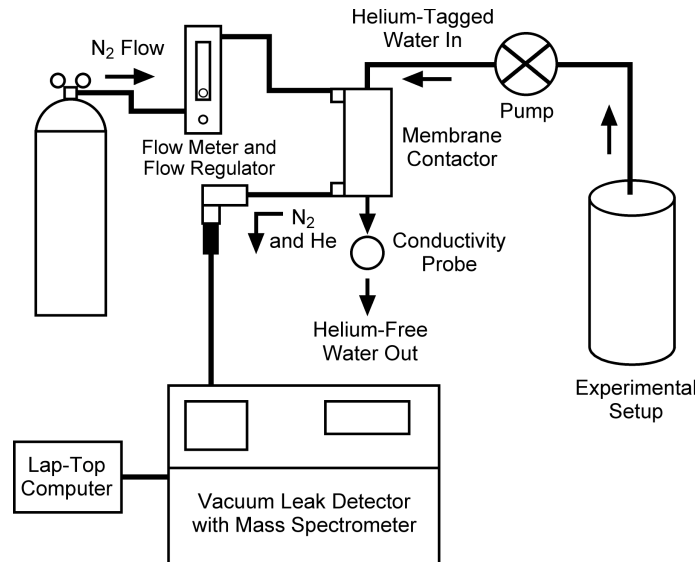


Figure 1. Schematic of the helium tracer system

Our system is built around a permeable membrane contactor, which is used commercially to extract dissolved gases from liquids. This contactor is a shell-and-tube device containing thousands of microporous hydrophobic polypropylene hollow fibers woven into a fabric array. To extract dissolved helium, a steady flow of helium-tagged water through the wet side of the contactor is maintained. A constant flow of clean, dry nitrogen through the gas side of the contactor provides a helium concentration gradient and results in the diffusion of helium from water to the gas side of the membrane contactor. Our design includes the use of the 6.35 cm \times 20.32 cm Extra-Flow Membrane from Liqui-Cel (Charlotte, NC). Nitrogen gas is moved inside the hollow fibers at a specified pressure. The rate of helium extraction depends on the partial pressure difference and the flow rate of water. Through calibration, a trial-and-error approach is used to estimate a certain combination of the flow rate and pressure. For example, at 13.8 N/s² the optimal flow rate is 10 cm³/s.

A vacuum leak detector probe is placed in the discharge path from the gas side of the membrane contactor. The leak detector has a helium-based mass spectrometer which generates an electrical signal that is proportional to the helium concentration in the gas discharge from the membrane contactor. This electrical signal is displayed as a leak rate.

A Veeco MS-40 Portable Leak Detector manufactured by Vacuum Instrument Corporation (Plainview, NY) was used in our design. The MS-40 detector is equipped with software that allows communication with a computer to automatically record output signals. The test port of the MS-40 detector is connected to the gas outlet of the extraction system by polytetrafluoroethylene tubing, which is permeable in regard to the small helium molecules. To prevent water vapor from entering the mass spectrometer's high vacuum chamber, a 33.02 cm \times 2.54 cm PVC cylinder filled with Drierite desiccants (0.64-cm granules) is placed in the flow line between the extraction system outlet port and the mass spectrometer's inlet port.

Instrument Calibration

The instrument was calibrated to convert signals from the helium detector to helium concentrations. Solutions of known concentrations were prepared based on the solubility of helium in equilibrium with atmospheric air at sea level (i.e., 5.0×10^{-5} mg/l) and the maximum solubility of helium at standard atmospheric pressure (i.e., 8 mg/l). Figure 2 shows the relationship between the concentration based on the helium signal recorded by the mass spectrometer and the known helium concentrations in the five helium solutions. A near-linear relationship exists between the two helium concentrations with a slope of the fitting line of 0.95. A potential error in results is likely due to the inability of the contactor membrane to extract all the helium gas from the solution.

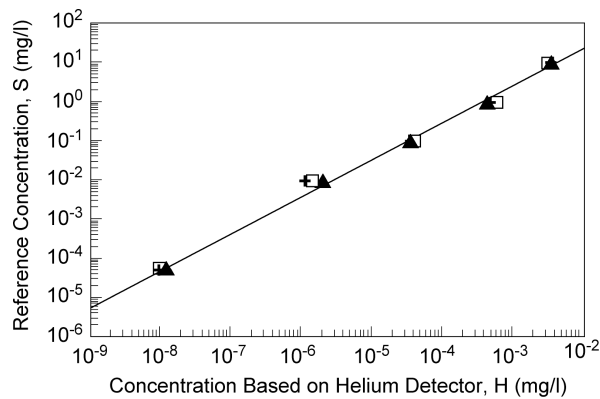


Figure 2. Instrument calibration curve using five different helium solutions. Three replicas (shown by different symbols) were tested for each solution. The solid line represents the least square best fit.

Principal Findings and Significance

Pipe Experiments

Water was pumped from a reservoir through a 6.1-m-long PVC pipe with a 5.08 cm diameter at a constant flow rate of $18.33 \text{ cm}^3/\text{s}$. Two 3.05-m pipes were connected by two 90-degree elbows to fit the experimental setup into the laboratory. An He/NaCl solution was injected into the pipes through a 0.64-cm inlet at the same constant flow rate of $18.33 \text{ cm}^3/\text{s}$ for 2 minutes. After the tracer injection, pumping from the water reservoir resumed for the remainder of the experiment. The 0.64-cm PVC pipe outlet was connected to the helium extraction and detection unit by 0.64-cm flexible PVC tubing. At the outlet of this unit the conductivity was measured by a probe. The relative He and NaCl concentrations were continuously recorded throughout the experiments.

The helium concentration results are compared against NaCl results in Figure 3 for one experiment. The success of the method is evident by the instantaneous response of the detection system to changes in solute concentration. Excellent match can be seen regarding the breakthrough curve, the first arrival, the slope of the curve, and the value of the relative peak concentration. However, the location of the peak in Figure 3 is slightly ahead for helium, and fluctuations are evident in the elution of helium. The resolution of the helium detector is a limiting factor in the accuracy of the readings, as is evident by the horizontal segments in the elution curve. The results were sensitive to a number of factors, including the helium saturation level in the injected water. Signals from the detector fluctuate if changes in their values occur over an order of magnitude in response to concentration variations.

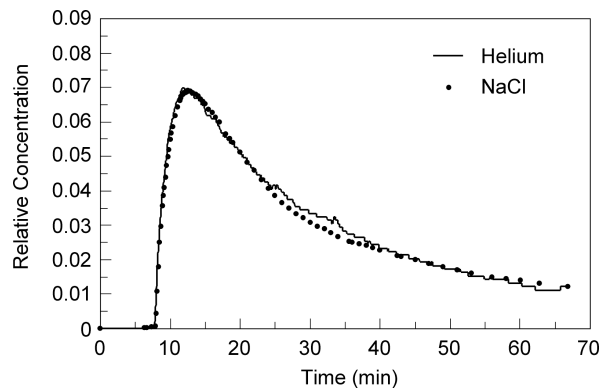


Figure 3. Concentration results for pipe experiment with NaCl and helium

Open-Tank Experiments

The experiments involved tracing a plume of dissolved helium and saltwater in an open tank (wedge shape of 244 cm length \times 60 cm width (at the widest part) \times 25 cm depth). NaCl dissolved in 3 liters of a saturated helium solution was injected at the wider end of the tank in about 15 seconds. At the opposite end, water was continuously pumped out of the tank and into the helium extraction/detection system at a specified rate. In some experiments, solute-free tap water was continuously injected into the tank at a specified rate.

The results showed that, compared to the helium curve, the first arrival and peak of the NaCl breakthrough curve were delayed by about 10 seconds. This can be explained by the different methods used to measure the two solutes. The conductivity probe is mounted in the line discharging the helium-free water from the membrane contactor (Figure 1). In this case, it seems it takes that many seconds for a water molecule to travel from the contactor membrane to the conductivity probe. Shifting the time axis by 10 seconds for helium showed that the two solutes are almost identical in terms of the breakthrough curve and the value of the peak (Figure 4).

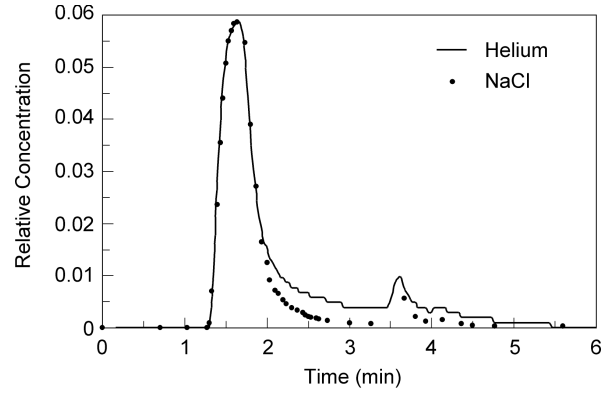


Figure 4. Concentration results for open-tank experiment with NaCl and helium

Another experiment included the introduction of two helium injections to test the ability of the detection system to respond to multiple-injection occurrences. The results are shown in Figure 5, where good overall match can be seen between relative concentrations of the two solutes, after shifting the time axis by 10 seconds for helium. However, loss of helium to the atmosphere is evident after about 6 minutes.

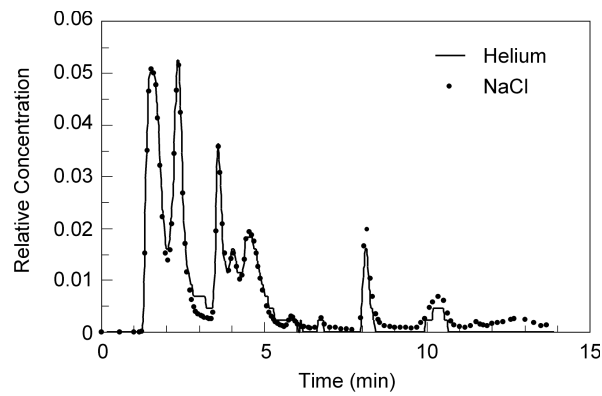


Figure 5. Concentration results for open-tank experiment O-3 with NaCl and helium. The experiment included two helium injection episodes.

The Dynamic Effects of Native Versus Non-native Vegetation on the Ecohydrology of a Hawaiian Rainforest

Basic Information

Title:	The Dynamic Effects of Native Versus Non-native Vegetation on the Ecohydrology of a Hawaiian Rainforest
Project Number:	2004HI57B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	Hawaii 1st
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Ecology, Models
Descriptors:	Ecohydrology
Principal Investigators:	Kaeo Duarte, Kaeo Duarte

Publication

Problem and Research Objectives

As populations increase and the demand for water rises, so does the need for informed sustainable resource management. In Hawai'i, one particular concern is that land use and vegetation change are adversely affecting groundwater recharge and thus freshwater supplies. While parcels of native forest are protected through the designation of water catchment areas, non-native plants threatening these forest parcels are believed to transpire more than their native counterparts or alter forest structure in a way that reduces groundwater recharge. However, these hypotheses have not been rigorously tested, and the hydrology of the typical Hawai'i watershed accounting for plant water uptake and growth has yet to be modeled.

Our current research objective is to test the specific hypothesis that vegetation change alters groundwater recharge by affecting the evapotranspiration (ET) term of the fundamental water balance equation. This is based on the hypothesis that many non-native invasive plant species are faster-growing and thus have higher transpiration rates than native species in Hawai'i, as suggested indirectly by physiological studies (Z. Baruch and G. Goldstein, 1999, Leaf construction cost, nutrient concentration, and net CO₂ assimilation of native and invasive species in Hawaii, *Oecologia* 121:183–92; R. Pattison, G. Goldstein, and A. Ares, 1998, Growth, biomass allocation and photosynthesis of invasive and native Hawaiian rainforest species, *Oecologia* 117:449–459; S. Cordell, R.J. Cabin, and L.J. Hadway, 2002, Physiological ecology of native and alien dry forest shrubs in Hawaii, *Biological Invasions* 4:387–396). However, scaling up these physiological rates to estimate native and non-native stand water use has not been performed in Hawai'i, and how these contribute to large-scale water balance is unclear. Architectural differences are also thought to affect ET within the forests, since it has been observed that disturbed non-native forest communities often have decreased understory and aerodynamic roughness, resulting in increased evaporation due to increased wind speed.

Since the inception of this project in 2004, focus has shifted from water balance modeling to the modeling of plant transpiration for dominant canopy and understory species in native and non-native forests. The objective is to generate species-specific transpiration models based on meteorological variables, soil water potential, and leaf area. These models can then be combined with vegetation data to estimate transpiration for any given stand.

Methodology

To address the question of how different forest communities affect the local water balance, we began by collecting meteorological data at two forested sites in South Kona, Hawai'i. One site, located in Kahauloa, is dominated by native canopy trees and tree ferns. The other site, which is less than 5 km away at Honaunau, has a canopy dominated by non-native timber trees including *Eucalyptus* and tropical ash. The understory of this non-native forest is relatively open and consists of the same native tree ferns as at the Kahauloa site. These two sites were selected to minimize environmental variation between sites and thus isolate ecohydrological effects due to vegetation differences. They were also chosen for their relatively flat grade and lack of observed surface runoff. Both are located at the same elevation of 1,000 m and are on substrate of the same age and type. Meteorological data was initially collected to verify that the two sites experience the same climate and rainfall events. Future work includes using meteorological data to estimate understory evapotranspiration at both sites.

The focus of this study is to determine the effects of vegetation on ET. Both ecological, physiological, and hydrological methods and equipment are used to this end. Primary tasks are summarized as follows:

1. Choose paired plots representing average native and non-native forests, and survey the vegetation.
2. Set up and monitor evapotranspiration stations at each of the two sites to measure solar radiation, air temperature, relative humidity, rainfall, wind speed, wind direction, and soil moisture. Evaluate ET with the Penman–Monteith equation, a well-known and established equation in hydrology.
3. Install pairs of soil-matric-potential blocks and TDR soil-moisture-content probes at each station, and use the data to define a soil moisture retention curve for estimating infiltration rates.

4. Estimate transpiration using xylem sap flow and leaf gas exchange methods.
5. Compute net infiltration by subtracting ET from rainfall and by using the physiological methods described in task 4.
6. Perform statistical analyses to determine uncertainty in the measurements, and compare native forest and non-native forest ET and infiltration.

Principal Findings and Significance

Results of meteorological data collected between June 2004 and April 2005 suggest that the two study sites have similar climates but their evaporative conditions may be quite different. Statistics have been run on a full year's worth of data with findings presented below.

Precipitation does not differ significantly between the two forested sites. Comparative analysis of rainfall and soil-moisture response indicates that the two sites are responding to the same climate regime. This result supports our assumption that forest-scale climate and elevation differences are minimal between the two sites. This allows us to focus our attention on how vegetation differences affect local soil moisture and infiltration conditions.

Data from the stations suggest that ET (of the understory) varies between the two forests. Mean wind speeds are over eight times higher in the non-native forest than in the native forest, implying that, all other parameters held constant, ET within the non-native forest should be much higher.

Compared to the non-native forest, humidity was slightly higher in the native forest. This may be related to the denser understory contributing to increased understory transpiration and reduced air flow. However, sampling from many more paired native and non-native sites needs to be performed to test this hypothesis.

Due to problems with the ET station equipment, complete soil moisture data and meteorological data from May 2005 to present is unavailable. The transition of this project in 2005 from one graduate student to another also delayed progress in ET modeling, and designing and building equipment for the transpiration measurements has taken up the last six months, pushing back actual measurements to summer 2006. Although USGS funding for this project has ended, work will continue with other funding. Following the completion of this research, results will be published in a master of science thesis.

Integrated Water Management with Multiple Aquifers

Basic Information

Title:	Integrated Water Management with Multiple Aquifers
Project Number:	2005HI103B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	First
Research Category:	Social Sciences
Focus Category:	Economics, Management and Planning, Law, Institutions, and Policy
Descriptors:	
Principal Investigators:	James A. Roumasset

Publication

1. Pitafi, Basharat; James Roumasset, Pareto-improving water management over space and time: The Honolulu case, under second review at American Journal of Agricultural Economics.
2. Pitafi, Basharat; James Roumasset, 2006, Evaluating interdependent watershed conservation and groundwater management reforms, Journal of the American Water Resources Association, forthcoming.
3. Pitafi, Basharat, 2004, Water Resources, Efficiency Pricing, and Revenue Recycling, Ph.D. Dissertation, Department of Economics, University of Hawaii at Manoa, Honolulu, Hawaii, 133 pages.

Problem and Research Objectives

We provide a general model of groundwater optimization over space and time, allowing for growing demand and a backstop resource. The model is used to compare resource allocation and welfare under efficient groundwater management and status quo management. We present a case study of a groundwater aquifer on the island of Oahu, namely, the Honolulu aquifer. To adequately represent local conditions, we require a general operational model of an exhaustible groundwater aquifer with variable recharge, the possibility of well salinization, desalting as a backstop source of freshwater, and growing water demand. Also, construction of a compensation scheme requires explicit disaggregation of consumers over space and time, as well as analysis of the distributional consequences of efficient management versus the existing inefficient management practice.

After solving for optimal management of the Honolulu aquifer, we will do the same for the Pearl Harbor aquifer. Once individual aquifer models are complete, we plan to integrate them into a single management model, allowing for hydrological interactions.

Methodology

The groundwater aquifers that provide freshwater in coastal areas, such as Honolulu, usually exhibit Ghyben–Herzberg lens geometry, where an underground layer of freshwater floats on saltwater that seeps in from the ocean (J.F. Mink, 1980, State of the Groundwater Resources of Southern Oahu, Board of Water Supply, City and County of Honolulu, Hawaii). If the freshwater is extracted faster than the rate of recharge, the freshwater head falls, the saltwater rises, and the freshwater layer becomes thinner. Since most pumping wells go deeper than the freshwater head, the rising saltwater can ultimately reach the bottom of the current well systems that will then begin to pump out saltwater. The freshwater head, therefore, needs to be constrained from falling below the level at which the well water would begin to turn saline. If more freshwater is required than that allowable under the constraint, it must be obtained through desalination of seawater, which serves as a backstop.

The rate of recharge and discharge of a coastal aquifer depends on the head level. As the head level rises, underground water pressure from a watershed decreases and the rate of recharge decreases. Also, leakage surface area and oceanward water pressure increase, and the rate of leakage increases. Thus net recharge varies inversely with the head level.

In most areas, groundwater users are geographically distributed. Users can be categorized according to their distribution costs. In Honolulu the distribution is over different elevations. In addition, the demand grows over time, depending on factors such as income and population.

Groundwater is typically considered a myopically exploited common property resource (see e.g., P. Koundouri, 2004, Potential for groundwater management: Gisser–Sanchez effect reconsidered, *Water Resources Research* 40:1–13; among many others). This results in a wedge (equal to marginal user cost) between marginal benefits and true marginal cost. Where water extraction is governed by an administered price, the same equilibrium obtains when, as in the Honolulu case, the regulatory authority implicitly sets price at an amount equal to the marginal physical cost of providing water. In Honolulu, status quo management introduces further inefficiencies as the authority sets a uniform price for different elevations—in effect cross-subsidizing high-elevation users.

To accurately model the above features, we require a generic operational model of status quo management and efficient spatial and temporal management of a renewable groundwater aquifer with variable recharge. We also need to allow for increasing demand and a backstop source of freshwater.

Users are distributed over different elevation categories. Consumption in elevation category i at time t is $q_t^i = D_i(p_t^i, t)$, where D_i is the demand function and p_t^i is the price. The second argument, t , of the demand function allows for any exogenous growth in demand.

Water is extracted from a coastal groundwater aquifer that is recharged from a watershed and leaks into the ocean from its ocean boundary, depending on the aquifer head level, h . Net recharge, l , is a positive, decreasing, concave function of head, i.e., $l(h) \geq 0$, $l'(h) < 0$, $l''(h) \leq 0$. The aquifer head level changes over time, depending on the net aquifer recharge and the quantity extracted for consumption at all elevations, $\sum_i q_t^i$. The rate of change of head level is given by $\dot{h}_t = l(h_t) - \sum_i q_t^i$, where β is the factor of conversion from volume of water in gallons (on the RHS) to head level in feet. However, in the remainder of this section we subsume this

factor, i.e., h is considered to be in volume, not feet. Thus, we use $h_t = l(h_t) \sum_i q_t^i$ as the relevant equation of head motion.

As the freshwater head level falls (depending on the extraction rate), the freshwater–saltwater interface rises. If the head level falls below h_{\min} , the interface rises to the level of well bottoms. Therefore, we measure head as the level above h_{\min} . Any expansion in demand when the head level falls to h_{\min} would need to be supplied by desalinated seawater. The unit cost of the backstop is represented by c_b , and the quantity of the backstop used in category i is b_t^i .

The unit cost of extraction is a function of the vertical distance water has to be lifted, $f = e - h$, where e is the elevation at the well location. At lower head levels, extraction is more expensive because the water must be lifted over a longer distance against gravity, and the effect of gravity becomes more pronounced as the lift, f , increases. The extraction cost is, therefore, a positive, increasing, convex function of the lift, $c(f) \geq 0$, where $c'(f) > 0$, $c''(f) \geq 0$. Since the well location is fixed, we can redefine the unit extraction cost as a function of the head level: $c_q(h) \geq 0$, where $c_q'(h) < 0$, $c_q''(h) \geq 0$, $\lim_{h \rightarrow 0} c_q(h) = \infty$. The total cost of extracting water from the aquifer at the rate q given head level h is $c_q(h) \cdot q$. The cost of transporting a unit of extracted water to users in category i is c_d^i .

We model water allocation first under status quo management and then under efficient management. The differences in welfare distribution under the two regimes are then examined and used to derive a mechanism to compensate those who lose welfare when the efficient allocation is implemented with marginal cost pricing and inframarginal blocks that balance the water authority's budget.

Principal Findings and Significance

We find that, compared to the status quo, efficient groundwater management in Honolulu increases welfare by 6.2%. The relatively large welfare gain, in comparison with that of other studies, is due to a combination of factors. Demand is large relative to the initial stock of water, but not so large that stock depletion will occur in the immediate future. In addition, the backstop price is relatively high, thereby contributing to the scarcity value of water.

By decomposing the sources of welfare gains, we find that the relative contributions of spatial optimization and temporal optimization depend on which comes first. In the Honolulu case, if spatial optimization is undertaken without temporal optimization, the gains are relatively small (about \$5 million). On the other hand, if temporal optimization is undertaken first (yielding \$227 million), the additional gains from spatial optimization are about \$180 million.

Temporal efficiency generates welfare gains by delaying aquifer exhaustion and the resulting need for expensive backstop technology. As such, the gains start at the time when status quo management would have resulted in the use of the backstop. Before this time, temporally efficient management causes welfare losses due to the higher efficiency prices. The gains from efficient management in Honolulu are \$441 million and the losses are \$34 million (or 7.7% of the gains) in present value terms.

Even though the gains from efficient management are larger than the losses, those who suffer losses can oppose efficient management. We provide a Pareto-improving mechanism for implementing efficient management. In the Honolulu case, we take 7.7% of the gains from the winners and use it to compensate the losers in each period. This is achieved by providing the losers an inframarginal free quantity of water, the value of which is equal to their welfare loss.

The urban Honolulu water district controls all of the water in the Honolulu aquifer. There are other water districts on Oahu with their own aquifers (e.g., Pearl Harbor aquifer). The aquifers minimally interact with each other through inter-aquifer percolation that is small enough to be ignored in most studies. Sophisticated engineering studies have considered such interactions, and integrating them with economic modeling is the next item on our research agenda. In addition, following the practice of the Honolulu Board of Water Supply, each water district consumes from its own aquifer, and inter-district transfers are not allowed. After repeating the methodology outlined above to solve for optimal management of the Pearl Harbor aquifer, we will solve for optimal joint management of the Honolulu and Pearl Harbor aquifers.

Diffusive Tortuosity of Reactive Porous Media: Application to Colloidal Fouling and Biofouling During Membrane Filtration

Basic Information

Title:	Diffusive Tortuosity of Reactive Porous Media: Application to Colloidal Fouling and Biofouling During Membrane Filtration
Project Number:	2005HI114B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	Hawaii 1st
Research Category:	Engineering
Focus Category:	Solute Transport, Water Quality, Models
Descriptors:	Porous Media, Colloidal Fouling, Biofouling, Membrane Filtration
Principal Investigators:	Albert Sechurl Kim, Albert Sechurl Kim

Publication

1. Kim, Albert S.; Huaqun Chen, 2006, Diffusive tortuosity factor of solid and soft cake layers: A random walk simulation approach, Journal of Membrane Science, in press.
2. Kim, Albert S.; Huaqun Chen; Rong Yuan, EPS biofouling in membrane filtration: An analytic modeling study, submitted to Journal of Colloid and Interface Science.
3. Chen, Huaqun; Albert S. Kim, 2006, Prediction of permeate flux decline in crossflow membrane filtration of colloidal suspension: A radial basis function neural network approach, Desalination 192, 415428.

Problems and Research Objectives

Fouling in microfiltration (MF) and ultrafiltration (UF) processes has been extensively studied for the crossflow filtration technique in which the flow direction is parallel to the membrane surface but perpendicular to the permeate flux. When rigid colloidal particles are removed by MF/UF membranes, the particles quickly form a concentration polarization (CP) layer above the membrane surface and contribute to the initial stage of permeate flux decline. During filtration, the concentration (i.e., volume fraction) of the colloidal particles above the membrane surface is mainly governed by particle size, solution ionic strength, Hamaker constant of the particles, membrane resistance, and applied pressure. Unless the inter-particle interactions are highly repulsive (e.g., small particles with high zeta potential in a feed solution of low ionic strength), the retained particles between the CP layer and the membrane surface form a cake layer whose volume fraction reaches a maximum packing ratio. In a (quasi-)steady state, the thickness of the cake layer increases with applied pressure, due to the increase in permeate velocity that accelerates particle transport from the bulk phase toward the membrane surface. The cake layer, therefore, provides much higher hydraulic resistance than the CP layer and causes significant permeate flux decline during MF/UF membrane processes.

The colloidal fouling mechanism in nanofiltration (NF) and reverse osmosis (RO) processes has quite different features from that in MF/UF processes. In the absence of particulate matter, the main cause of flux decline in NF/RO processes is the CP of solute ions. This is because the wall concentration, i.e., solute concentration on the membrane surface, determines the effective driving force, i.e., the applied pressure minus the osmotic pressure difference between the surface and permeate sides of the membrane. In the presence of colloidal particles within the feed solution of NF/RO processes, the particles also form CP and cake layers on the membrane surfaces, where the hydraulic resistances from the layers are almost negligible compared to the inherent resistances of NF/RO membranes. Nevertheless, the cake layer containing retained particles produces significant permeate flux decline by obstructing back diffusion of the solutes. To diffuse from the vicinity of the membrane surface toward the bulk phase, the solutes need to avoid the retained particles by taking tortuous paths within the colloidal cake layer. Therefore, back diffusion is hindered, CP is enhanced, osmotic pressure is elevated, and permeate flux is suppressed to a certain extent. This phenomenon is called cake-enhanced osmotic pressure or cake-enhanced concentration polarization.

When biological matters are rejected by pressure-driven membrane processes, the filtered material forms a biological cake layer, called a biofilm, which causes deleterious biofouling. This is operationally defined as an unacceptable degree of system performance loss. The initial formation of the biofilm involves the accumulation of microorganisms (e.g., bacteria, fungi, microalgae) at a phase transition interface between the microorganism CP layer and the membrane surfaces. The bacterial accumulation occurs in two consecutive steps: initial attachment followed by ensuing growth. In this light, biofouling of the membrane surfaces is more problematic than abiotic colloidal fouling or solute precipitation because attached cells degrade the surface of polymeric membranes and multiply in a geometric fashion using nutrients continuously supplied from the feed water. Therefore, a single bacterium entering a membrane module may cause extensive biofouling if the growth rate of the sessile population is high.

The adhesion capability of bacteria to the membrane surface increases with respect to time, due to the biosynthesis of adhesive extracellular biopolymers that are abundantly produced and envelop the attached cells in viscous hydrated gels. The biopolymers are referred to as *extracellular polymeric substances* (EPS). They enhance the survival and robustness of the biofilm microorganisms by serving as a transport barrier to reactive chemicals such as antimicrobial agents trying to penetrate the biofilm by convective and diffusive transport mechanisms. Turbulent mixing above the membrane surface is also diminished by the presence of EPS that causes enhanced concentration polarization of solutes accumulating in the viscous sublayer. The biofouling is greatly affected by the micro-structure and composition of the membrane biofilms. In contrast to the axial shear flow experienced by biofilms, a noticeable proportion (10% to 15%) of the fluid containing water, nutrients, and other solutes can continuously pass through the biofilms due to the transmembrane pressure, thereby feeding the microorganisms and accelerating biofilm growth kinetics. High transmembrane pressure either condenses or compresses the biofilms and generates highly dense structures with minute porosity. The thickness of the biofilm varies from mono- to multi-layers of cells that are typically distributed throughout the EPS matrix. The voids and heterogeneity of the biofilms are still not well understood, but the impact can be extraordinary because the solutes, including nutrients present in the feed solution and biocides added for cleaning of biofouled membranes, will be trapped within the small void pores of the biofilm. Their back diffusion will be commonly hindered, causing a similar phenomenon to the cake-enhanced osmotic pressure in colloidal fouling, but to a more severe extent.

In this light, a fundamental understanding of solute diffusion within colloidal cakes and biofilms is of great importance, especially when the solutes are reactive to the sphere surfaces due to electric/chemical/physical interactions. In membrane filtration, the porous media consisting of rejected matter on the membrane surfaces can be classified into two categories: solid and soft cakes. The solid cake refers to the colloidal cake layer composed of rigid and (typically) spherical particles, whereas the soft cake characterizes the biofilm composed of deformable or compressible microorganisms usually surrounded by EPS. In both cases, the finite sizes of the cake reduce the free spaces in which the solute can perform Brownian random motion, and so the solute back diffusion from the membrane surface to the bulk phase is greatly hindered by their presence. In addition to the role of the cakes as geometrical obstacles to the diffusing solutes, interaction between the sphere surface and the solutes remarkably affects overall effective solute diffusion. Only solutes present in void spaces of the cake layers can contribute to the osmotic pressure.

Methodology

Two fundamental approaches were used to investigate the effects of solid and soft cakes on pressure-driven membrane filtration: Pearsonian random walk simulation and mean-field transport theory.

Pearsonian Random Walk Simulation

Solid cake (i.e., deposition layer of colloidal particles) and non-reactive soft cake (i.e., deformable biofilm surrounded by EPS in an equilibrium state) were investigated using the random walk simulation method. In the simulation, inert solutes were arbitrarily located within void spaces of the cake layers (described above) and allowed to move in a random manner. Their movements, being partially rejected by solid and deformed cake structures, were traced and statistically analyzed.

Theoretical Approach for EPS Biofouling Using Mean Field Approximation

Mass transport through a biofilm in the presence of EPS layers was modeled using a spherical cell model with a mean-field approximation. A cell is composed of a bacterium surrounded by excreted EPS. Transport of solutes through the EPS layer is represented by a solute diffusivity which is assumed to be smaller than bulk diffusivity. Solute uptake flux by bacteria was neglected because the flux is assumed to be small enough not to change solute concentration on the membrane surface.

Principal Findings and Significance

Random walk simulation analyzes the significance of deformed cake structure on solute diffusion. Cake deformation changes the pore structure from partially restricted free space to network-like, connected void channels. Therefore, the non-reactive, deformed soft cake provides a remarkable increase in diffusive tortuosity and causes the permeate flux decline. Results appear in a *Journal of Membrane Science* article that is currently in press (see list of publications for this project). In addition, results were presented at the International Congress on Membranes and Membrane Processes, Seoul, Korea, August 21-26, 2005. The conference presentation was entitled "Diffusive Tortuosity Factor of Colloidal Cake and Biofilm."

The theory of EPS effects on permeate flux provides a clear understanding that hindered diffusion within an EPS layer inhibits solute back diffusion from the membrane surface to the bulk phase. This is mainly because of the presence of bacteria causing geometrical obstruction as well as partition of solutes between the EPS layer and bulk phase. Results are reported in a paper submitted to the *Journal of Colloid and Interface Science* (see list of publications). In addition, research outcomes will be presented at the annual symposium of the American Chemical Society, to be held in San Francisco, September 2006, pending acceptance of the abstract, entitled "EPS Biofouling in Membrane Filtration: An Analytic Modeling Study."

Coastal Groundwater Management in the Presence of Positive Stock Externalities

Basic Information

Title:	Coastal Groundwater Management in the Presence of Positive Stock Externalities
Project Number:	2005HI125G
Start Date:	9/1/2005
End Date:	8/31/2008
Funding Source:	104G
Congressional District:	HI 1
Research Category:	Social Sciences
Focus Category:	Hydrology, Economics, Ecology
Descriptors:	None
Principal Investigators:	Kaeo Duarte, James A. Roumasset

Publication

Problem and Research Objectives

Hawaii's nearshore marine environment, which is a major recreational and ecological resource, is dependent on fresh groundwater discharge. Freshwater discharges from the groundwater aquifer into the ocean and mixes with the seawater creating a nearshore ecological system that has evolved with less than seawater salinity and which supports indigenous fish and marine vegetation. Thus, the state of the groundwater aquifer directly affects the cultural, recreational, and economic values of the community. As water is extracted from the groundwater aquifer to meet growing demand, lower aquifer head levels will decrease discharge into the ocean, thus increasing salinity and damaging the balance of the nearshore marine ecosystem. Traditionally, models of optimal groundwater extraction do not include such environmental effects. The problem, therefore, is to govern groundwater extraction based on considerations of environmental consequences as well as present and future benefits of water consumption. This requires economic models that incorporate the relation between what is pumped from the aquifer and the growth and availability of nearshore fish and marine vegetation.

Methodology

The model applied here closely follows that of Krulce et al. (1997) which in turn is an application of optimal control mathematics. The objective is to choose a path over time for extraction of groundwater and production of desalinated water in order to maximize the present value of net social surplus from water. The social surplus covers both traditional water uses and external benefits from production of indigenous fish and marine vegetation in nearshore waters affected by discharge of freshwater from aquifers. Mathematically, the problem may be stated as

$$\max_{q_t, b_t} \int_0^{\infty} e^{-rt} \left[\int_0^{q_t + b_t} p(x) dx - c(h_t) q_t - \bar{p} b_t + \int_0^{m_t} p_m(y) dy - c_m(S_t) m_t \right] dt \quad (1)$$

$$s.t. \quad \dot{h}_t = a[R - l(h_t) - q_t] \quad (2)$$

$$\dot{S}_t = g(S_t, h_t) - m_t \quad (3)$$

In Equation (1), the first integral in square brackets expresses the value of traditional uses water, net of pumping and desalinating costs. The second integral adds the net value of offshore vegetation and fish living in the mixed fresh and saline waters affected by fresh groundwater discharge. Empirical versions of the latter function will be explored in the laboratory as described below. Equations (2) and (3) connect groundwater withdrawals to the growth of offshore vegetation, and recognize traditional pumping-head level-recharge effects in the aquifer. These three equations constitute an optimal control problem, the solution to which will include economically efficient paths, over time, of groundwater extraction, head level, quantities of desalination and of vegetation harvesting.

The function $g(S_t, h_t)$ in Equation (3) is the growth function for the nearshore

vegetation and is the subject of the laboratory phase of this project. An environmental growth chamber will be constructed to precisely control both temperature and light in a standardized manner throughout the various trials.

Control and treatment water will be pumped at a specific rate from 55-gallon barrels located outside the chamber into beakers randomly placed in two water baths. The water will then slowly spill over the edge of the beakers into the bath, which will act as a thermoregulator for the beakers. This design allows the water bath to buffer any variability that may exist at different locations in the growth chamber. The growth response of the vegetation, i.e., algae, will be measured by the rate of change in wet weight over a period of two weeks in response to different levels of the treatment variable. The levels of the treatment variable will be of sufficient range to identify the conditions necessary to achieve maximum and minimum growth rates.

Principal Findings and Significance

In the first months of this three-year project, attention was directed to economic modeling and to constructing laboratory apparatus for empiricizing some of the functions in the economic model.

Optimal control mathematics leads to expressing the problem expressed in equations (1) to (3) above in Hamiltonian form, with established procedures for solving for steady-state pumping and vegetation harvesting. Here, we mention only two of the resulting first-order conditions, which express the external effects of groundwater pumping. Extracting water from the aquifer, and harvesting the marine vegetation, should be carried on at such rates as to satisfy, first,

$$r\lambda_2 + \lambda_2 a'(h) = \dot{\lambda}_2 - c'(h)q + \theta g_h(S, h) \quad (4)$$

(the marginal cost of water conservation [left-hand side] should equal its marginal benefit; the final term, in particular, expresses the additional marginal benefit due to the value of nearshore vegetation). Second,

$$\bar{p} = c(h) - \frac{a(R - I(h))c'(h)}{r + a'(h)} + \frac{ag_h(S, h)\theta}{r + a'(h)} \quad (5)$$

(the marginal benefit of pumping water from the aquifer should equal the marginal cost of pumping, including, in the final term, the added marginal cost due to the external effect of pumping on nearshore vegetation). In both equations, the final terms would not appear if the analyst ignored external effects of pumping the aquifer. These terms indicate that head should be kept at a higher level to account for non-market values of marine vegetation.

The laboratory phase of the project concentrates on three endemic edible species of seaweed with high economic and cultural value, as identified by a search of the literature. For these species, we are creating an experimental design to accurately detect and measure changes in growth rate in response to varied levels of salinity, nitrogen, phosphorus, and temperature.

The environmental growth chamber is currently under construction. It is being modified to accommodate a flowing seawater system to resemble more accurately natural conditions on the reef.

It is expected that each of the three different species of marine algae will respond differently to the various treatments. It is believed that increased amounts of submarine groundwater discharge will promote an elevated growth rate in at least one of the species. The minimum and maximum growth rates for these algae are most likely not dependent on a single variable but rather the overall synergistic effect of these water quality parameters.

Grant No. 05HQGR0171 Stormwater Education on US Army Installations on Oahu

Basic Information

Title:	Grant No. 05HQGR0171 Stormwater Education on US Army Installations on Oahu
Project Number:	2005HI172S
Start Date:	9/15/2005
End Date:	9/14/2007
Funding Source:	Supplemental
Congressional District:	First
Research Category:	Social Sciences
Focus Category:	Education, Water Quality, Surface Water
Descriptors:	Environmental education, Watersheds, Stormwater
Principal Investigators:	John Cusick

Publication

Problem and Research Objectives

Current water quality measurements within storm-drain discharge locations on military bases on Oahu indicate that the U.S. Army will not meet standards for total suspended solids, nitrogen, and phosphorous. Assessments suggest that exceedances are due to erosion of non-vegetated areas, including housing facilities. As part of an overall remedy, the Army needs to develop a permanent program that involves stormwater education at the schools on its base installations.

A goal of this project is to increase awareness and understanding of stormwater-related problems in the watersheds of central Oahu, particularly that of Waikele Stream. Located, in part, on Army installations, it is identified by the State of Hawaii as a watershed at risk. This project introduces stormwater education to public elementary- and middle-school students on Wheeler Army Airfield and Schofield Barracks installations. A key learning objective is to improve individual responsibility for stewardship of environmental quality and to change human and institutional behaviors that permit or condone polluting activities.

Methodology

The Environmental Center at the University of Hawaii at Manoa is collaborating with Bishop Museum and Pacific Consulting Services, Inc. to determine relevant and effective stormwater education materials and curriculum activities. Project participants are reviewing existing curricula related to watershed education in elementary and middle schools and will incorporate this information into a series of hands-on learning exhibits. Geographic information, including topography and rainfall, of central Oahu will be highlighted in all materials developed by the project. Field sites near the schools on Army installations (i.e., those sites that exhibit signs of erosion and provide opportunities for teaching improved stewardship) will be identified for potential future monitoring by student groups. Additional funding will be pursued to expand the project to other school communities in the state of Hawaii.

The current funding provides for one "Water Works Festival" to be held at either the Wheeler or Schofield Army installation. The festival, to be held on an evening during the spring of 2007, will be open to all military personnel living and working on both Army bases, their families, and staff of the public schools. The festival exhibits will be a diverse array of hands-on science, engineering, and cultural activities designed for multi-generational interactive learning. The activities will center on topics including watersheds, the water cycle, aquatic ecosystems and biota, ground- and surface-water resources, water quality, stormwater and wastewater infrastructure, and pollution prevention. A geographic information system (GIS) presentation will introduce the technology and its capabilities as an educational tool. Bishop Museum science and cultural education specialists are preparing exhibits for the festival, and Pacific Consulting Services will develop and incorporate the web-based GIS technology, GIS/mapping exercises, and resource links. All project data will be accessible on the Environmental Center website.

Principal Findings and Significance

The project has no findings to report at present. The preliminary phase of literature review and stakeholder meetings was completed, and preparations for the 2006–2007 school year are being made with Bishop Museum and Pacific Consulting Services.

Grant No. 05HQGR0178 Evaluating the Effectiveness and Feasibility of Commercial Ozone Technologies Used for Sanitation of Work Area and Laundry Services

Basic Information

Title:	Grant No. 05HQGR0178 Evaluating the Effectiveness and Feasibility of Commercial Ozone Technologies Used for Sanitation of Work Area and Laundry Services
Project Number:	2005HI173S
Start Date:	9/1/2005
End Date:	12/31/2006
Funding Source:	Supplemental
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Water Quality, Treatment, Water Use
Descriptors:	ozone, disinfection, bacteria, water quality
Principal Investigators:	Roger Fujioka

Publication

Problem and Research Objectives

The primary goal of this study is to obtain independent, laboratory-based performance data to evaluate the effectiveness, feasibility, and safety in the application of a commercial ozone technology (Ozone Industries, Inc.) for cleaning and disinfection (i.e., sanitation) of workplace surface areas and for cleaning and disinfection of linen and clothes (laundry services). A secondary goal is to evaluate the economic benefits of using ozone technologies.

Methodology

The overall experimental design of this study is to assess the quality of sanitation of surface areas and laundry products before and after treatment with ozone technology and with non-ozone technology. The quality of sanitation will be determined using traditional human senses (sight, touch, smell) as well as laboratory data to document the performance of the ozone and non-ozone treatments. Laboratory data to assess the quality (cleanliness, safety) of the treated products will be based on measuring, before and after treatment, selected parameters such as blood, dirt, oil, and protein stains, as well as surfactants and total microbial load. To obtain more reliable and quantitative data, known concentrations of stains or non-pathogenic bacteria (*Bacillus* spp.: soil bacteria) will be added to workplace surface areas or laundry products. Then the percentage of the contaminants remaining on the surface areas or laundry products after cleaning by ozone and by non-ozone treatments will be determined. By comparing the resulting data, the effectiveness by which the ozone technology and non-ozone technology removes stains, surfactants, and total microbial load can be determined. It should be noted that the ozone technology for treatment of workplace areas and that for laundry services differ and the products to be treated differ as well. Thus, although the same overall approach and many of the same assay methods will be used to assess these two different applications of ozone technology, there will be some differences in the approaches and methods used. For example, to assess ozone technology for laundry services, some samples of input water and wastewater from ozone and non-ozone treatment processes will be analyzed for some of the same contaminants as well as additional parameters (ozone, oxidation-reduction potential, conductivity, temperature, disinfection potential). Based on the resulting measurements, the waste load and hazard load of the wastewater for each of the treatment processes can be determined. To obtain good data, each ozone site must be sampled a minimum of three times on three different days when conditions are typical for that operation. The averages of the three tests will then be used to draw conclusions on the effectiveness of the respective systems. If any system is not operating within the range of expectations during the day of the experiment, the data for that day may be rejected or summarized with data obtained when the system was working properly. The intent is to obtain good experimental data for five different days for ozone-treated systems.

Principal Findings and Significance

To clean supermarket cutting boards, ozone treatment was the third process used after detergent treatment and surfactant treatment. The first two treatments removed/disinfected most of the surface bacteria, but none of the three treatments disinfected the bacteria formed as a result of biofilm growth. However, the biofilm bacteria most likely do not pose a health threat. Ozone, delivered in low concentrations, was shown to disinfect 90% of the bacteria suspended in water. Our data show that bacteria grown as part of a biofilm are resistant to disinfection by the ozonated water used at the supermarket. These results support previous reports that populations of bacteria in a biofilm are much more resistant to disinfection than the same bacterial population suspended in water.

For the laundry experiment, the ozone treatment and non-ozone treatment cleaned laundry to the same extent. Thus, when ozone was not available, laundry was still cleaned satisfactorily. This is because the high amount of detergent used can clean fabrics in the presence or absence of ozone.

The company providing ozone services did not consistently deliver high concentrations of ozone. Moreover, the manner in which the ozone was applied did not allow one to test the effectiveness of ozone

technology. Another ozone technology should be tested to evaluate the effectiveness of using ozone to clean and disinfect laundry and to disinfect supermarket cutting boards.

Information Transfer Program

Technology Transfer

Basic Information

Title:	Technology Transfer
Project Number:	2005HI120B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	first
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Philip Moravcik

Publication

Information Transfer Program

WRRC's Technology Transfer program activities included: organization of a seminar series, production of project bulletins and newsletters, participation in conferences, and providing information to consultants, students of all levels, and the public. Program personnel also participated in school science fairs, research projects having an informational component, and refinement of the Center's web site. This year the Technology Transfer program produced 2 newsletters describing research projects, Center activities and news.

During this reporting period the Center invested in a large-format printer/plotter which has received extensive use producing posters for display at meetings and conferences locally, nationally, and internationally. This investment has proven to be most productive as the trend towards poster presentations at conferences has been increasing in recent years.

The Information Transfer Program organizes a biweekly seminar series designed to foster communication amongst WRRC researchers, students, and target audience of government agencies, private sector personnel and members of the public with an interest in water resource issues. A WRRC faculty member is appointed each semester to organize the seminar and recruit speakers from University faculty, visiting scientists, government agencies and private sector firms. Topics thus vary depending on the interests of the coordinator and availability of speakers. Typically the seminars include reports on WRRC projects and discussions by government officials of emerging water-related issues. The seminars are generally well attended and provide one of the few public forums for the discussion of water issues in the state. The following is a list of the seminars presented during the reporting period.

Spring 2005, Seminar Coordinator: Roger Fujioka

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| 3/3/2005 | Lorin Pang, MD, MPH, Maui District Health Officer, Hawaii Department of Health Investigations to Evaluate complaints of Maui's Upcountry drinking Water Additives |
| 3/10/2005 | Till Rubbert, Chair of Applied Geology, Ruhr-University Bochum (Germany)
The Efficiency of Clay-Cement-Suspensions as Grout Seals in Water Wells |
| 3/17/2005 | Woodie Muirhead, Brown & Caldwell, Honolulu, HI
Assessment of a Research Project to Use Wastewater for Irrigation in Central Oahu |
| 4/7/2005 | (1)Ken Kawahara Acting Regulatory Control Branch Head, City & County of Honolulu, Dept of Environmental Services, , (2) James Carmichael, Vice President, Synagro Technologies Inc. and (3)Harold Yee, Wastewater Branch Chief, Department of Health, State of Hawaii
Update of Sludge Reuse Issues for the City and County of Honolulu and Implementation of New Sludge Treatment and Recycling Technology for Sand Island Wastewater Treatment Plant |
| 4/21/2005 | (1) James Honke, CCH, DES-Retired and (2) Victor Moreland, Ph.D., WRRC, UH
Update on Issues Related to Ocean Discharge of Sewage and Evaluation of the City and County of Honolulu Decision to Disinfect Sand Island Primary Treated Sewage Effluent Using Ultra-Violet (UV) Technology |

- 5/5/2005 Watson Okubo, Section Head, Environmental Management Division, Clean Water Branch, Department of Health, State of Hawaii
Update on Beach Monitoring Program for Fecal Indicator Bacteria in Hawaii
- 5/27/2005 Dr. Albert Koenig, Hong Kong University
Challenges in the Planning and Design of the Harbour Area Wastewater Treatment Scheme in Hong Kong

Fall 2005, Seminar Coordinator: Aly El-Kadi

- 9/1/2005 Ali Fares, Associate Professor of Hydrology, NREM, University of Hawaii Manoa
Hydrological Aspects Hawaiian Watersheds
- 9/15/2005 K. Kodama & Y.L. Chen, P.S. Chu and D. Stevens, Department of Meteorology, UH
Meteorological Aspects of the October 2004 Manoa Flood
- 9/22/2005 Larry Barber, Research Geochemist, USGS National Research Program, Boulder, CO
Consumer Products Environmental Endocrine Disruption and Aquatic Ecosystems
- 10/6/2005 Derek Chow, Civil & Public Works Branch, US Army corps of Engineers
Structural and Non-Structural Flood control Features
- 10/20/2005 Clark C.K. Liu, Professor, UH Department of Civil & Environmental Engineering & WRRRC & Krispin Fernandes, WRRRC Graduate Research Assistant
Hydrologic Aspects of October 2004 Manoa Flood
- 11/3/2005 Rick Fontaine, USGS Honolulu Office
Manoa Flood of October 30, 2004: Hydrologic Data Collection and Interpretation
- 11/17/2005 Aly El-Kadi, Associate Professor, Geology & Geophysics & Water Resources Research Center
Modeling Stream Flows and Flood Delineation of the Manoa 2004 Flood
- 12/1/2005 Thomas Giambelluca, Geography Department, University of Hawaii Manoa
Estimating Recharge in Hawaii

Spring 2006, Seminar Coordinator: John Cusick

- 1/19/2006 Dr. Gerry Marten, fellow, East-West Center
Environmental Tipping Points: A New Paradigm for Strategic environmentalism
- 01/27/2006 Daniel Y. C. Fung, Professor Kansas State University
25 Years of Rapid Methods and Automation in Microbiology: Current Trends and World Market Prediction
- 02/02/2006 Yacov Tsur, Professor, Department of Agricultural Economics and Management, the Hebrew University of Jerusalem
Economic Aspects of Irrigation Water Management

02/10/2006 Aly El-Kadi, Associate Professor, Geology & Geophysics & Water Resources Research Center
Use of Dissolved Helium as an Environmental Water Tracer

02/16/2006 Ramsay Taum, UHM Travel Industry Management
Connecting Hawaii's Past to Hawaii's Future: Water Use

Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	1	0	0	1	2
Masters	4	1	0	2	7
Ph.D.	4	1	1	0	6
Post-Doc.	1	0	0	0	1
Total	10	2	1	3	16

Notable Awards and Achievements

Publications from Prior Projects

- 2004HI60B ("Application of Innovative Methods and Strategies to Differentiate Sewage from Non-Point Source Pollution in Hawaii") - Dissertations - Brostrom, Kathleen England, 2005, Are Fecal Sterols a Possible Alternative Indicator of Human Waste Contamination in Hawaiian Recreational Waters?, MS Thesis, Department of Microbiology, University of Hawaii, Honolulu, Hawaii, 136 pages.
- 2001HI2082B ("Confirming the Natural Presence of Fecal Indicator Bacteria in Environmental Soil and Water on the Islands of Kauai and Hawaii") - Dissertations - Vithanage, Gayatri, 2005, Assessing the Source of Fecal Contamination in Streams on Kauai Based on Concentration and Genotypes of FRNA Bacteriophages, MS Thesis, Department of Microbiology, University of Hawaii, Honolulu, Hawaii, 91 pages.
- 2003HI26B ("Prevention of Colloidal Fouling in Crossflow Membrane Filtration: Searching for Optimal Operation Conditions") - Articles in Refereed Scientific Journals - Chen, Jim; Albert S. Kim, 2006, Monte Carlo simulation of colloid membrane filtration: Principal issues for modeling, Advances in Colloid and Interface Science, 119, 3553.
- 2001HI14S ("Optimize Aeration, Secondary Clarifier and Disinfection Processes") - Articles in Refereed Scientific Journals - Moreland, Victor; Roger Fujioka, 2005, Water management and water reuse, Journal of Harbin Institute of Technology, 12, 4045.
- 1990HI02B ("An Efficient Technique for Solving Unsaturate Flow and Solute Transport Problems") - Articles in Refereed Scientific Journals - El-Kadi, Aly I., 2005, Validity of the generalized Richards equation for the analysis of three-dimensional test data for a coarse-material aquifer, Vadose Zone Journal, 4, 196205.
- 1990HI102B ("An Efficient Technique for Solving Unsaturate Flow and Solute Transport Problems") - Other Publications - El-Kadi, Aly I., 2005, Unconfined ground water, in The Encyclopedia of Water, edited by J. Lahr and J. Keeley, John Wiley and Sons, New York.
- 2003HI27B ("An Evaluation of Factors Affecting the Transport of Pharmaceutical Compounds and

- Pathogens in Selected Hawaii Soils for Land Application of Wastewater") - Other Publications - Mohanty, S.K.; M. Snehota; C. Ray; J. Chen; J. Lichwa, 2005, Transport of selected wastewater contaminants in tropical soil, Geophysical Research Abstracts, 7, 07481.
8. 2001HI2141B ("An Accurate Evaluation of Water Balance to Predict Surface Runoff and Percolation") - Other Publications - Ray, Chittaranjan, 2005, The next best thing, Civil Engineering, 75(7), 5863.
 9. 2003HI27B ("An Evaluation of Factors Affecting the Transport of Pharmaceutical Compounds and Pathogens in Selected Hawaii Soils for Land Application of Wastewater") - Water Resources Research Institute Reports - Snehota, Michal; Jingyu (Joey) Chen; Sanjay Mohanty; Joseph Lichwa; Chittaranjan Ray, 2005, Column Study of the Transport of Selected Contaminants in a Hawaii Soil Treated With Recycled Water, Water Resources Research Center, University of Hawaii at Manoa, Honolulu, Hawaii, 48 pages.
 10. 2001HI701B ("Removal of Nitrogenous Aquaculture Wastes by a Wind-Powered Reverse Osmosis System") - Articles in Refereed Scientific Journals - Qin, G.; C.C.K. Liu; N.H. Richman; J.E.T. Moncur, 2005, Aquaculture wastewater treatment and reuse by wind-driven reverse osmosis membrane technology: A pilot study on Coconut Island, Hawaii, Journal of Aquaculture Engineering, 32, 365378.
 11. 2001HI701B ("Removal of Nitrogenous Aquaculture Wastes by a Wind-Powered Reverse Osmosis System") - Articles in Refereed Scientific Journals - Liu, C.C.K.; C. Ice; J.K. Levy; J. Moncur, 2005, Institution, policies, and technologies for sustainable watershed management in the Asia-Pacific, Water Resources Impact, 7(2), 69.
 12. 2001HI701B ("Removal of Nitrogenous Aquaculture Wastes by a Wind-Powered Reverse Osmosis System") - Conference Proceedings - Liu, C.C.K.; W. Xia; J.W. Park, 2005, A wind-driven reverse osmosis system for wastewater reuse and nutrient recovery, in Proceedings of IWA Specialty Conference WRRS2005: Wastewater Reclamation & Reuse for Sustainability, Nov. 8-11, 2005, Ramada Plaza, Jeju, Korea, International Water Association, 7 pages (CD-ROM).