Water Resources Center
Annual Technical Report
FY 2002

Introduction

The UC Center for Water Resources is a multicampus research unit and a special program within the university of Californias Division of Agriculture and natural Resources. The major function is to support research and extension activities that will contribute to the efficient management of water resources within the state. Meeting the needs of the urban, agricultural and wildlife sections from both water quality and quantity considerations is a goal of the Center. The Center has linkages to faculty on all nine campuses in the UC system and to extension personnel in each of the 58 counties. The Center can be reached by email at cwres@ucr.edu and can be viewed on the web at http://waterresources.ucr.edu

Research Program

The Water Resources Center funded 16 new projects and continued 16 projects for a total of $910,599.00 with nearly every UC Campus participating.

Fate of viruses, endocrine disrupters, and nitrogen in non-conventional onsite wastewater treatment processes: a technical and economic analysis

Basic Information

Title:	Fate of viruses, endocrine disrupters, and nitrogen in non-conventional onsite wastewater treatment processes: a technical and economic analysis
Project Number:	2002CA1B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	43
Research Category:	None
Focus Category:	Waste Water, Treatment, Nitrate Contamination
Descriptors:	None
Principal Investigators:	Jeannie L Darby, Paul Sabatier

Publication

1. Leverenz H., G. Tchobanoglous, and J. Darby (2002) Review of Technologies for the Onsite Treatment of Wastewater in California, Center for Water Resources Engineering, University of California Davis, No. 2002-2. Leverenz H., L. Ruppe, G. Tchobanoglous, and J. Darby (2001) Evaluation of High Porosity Media for the Treatment of Onsite Treatment of Wastewater, (peer reviewed) Small Flows Journal, Vol. 2, No. 2.

Project Summary

Onsite wastewater treatment systems have been constructed and are currently in operation at the UC Davis wastewater treatment facility for investigation of the fate of indigenous coliphage, nitrogen, and endocrine disruptors in these systems. The treatment systems that have been selected for evaluation are unique because of their high efficiency and role in the future of onsite wastewater treatment. The treatment systems that are in operation encompass several state-of-the-art technologies, including (a) three high porosity, high surface area multi-pass biofilm reactors (see Fig. 1), (b) two submerged aerated biofilm reactors; one to be inoculated with specific bacteria (i.e., bioaugmentation) for enhanced performance (see Fig. 2), and (c) a traditional septic tank followed by single-pass sand filters. In addition, soil lysimeters (see Fig. 3) have been assembled to further evaluate the effect of upstream processing on the performance of soil adsorption systems (i.e., standard leach field).

The treatment systems described above are typically used for the treatment (or pre-treatment) of wastewater from individual or clustered buildings or small communities before discharge to the soil environment. After discharge to the soil, the partially treated wastewater undergoes additional treatment by soil microorganisms, followed by evaporation or infiltration to the local groundwater. Constituents that are typically present in wastewater include dissolved and particulate organic materials, nutrients, pathogenic and non-pathogenic microorganisms, and chemicals resulting from human activities (e.g., hormones, pharmaceuticals). These constituents are removed to varying degrees depending on the nature of the treatment process used. The purpose of the present research is to determine the fate of these constituents when treated in conventional and non-conventional treatment systems and after discharge to the soil.

Due to the nature of the treatment systems, it will be possible to evaluate the removal and transformation of wastewater constituents under a range of conditions. For example, based on preliminary research, the biofilm reactors are able to provide nearly complete BOD and TSS removal, complete nitrification, and 30 to 70 percent total nitrogen removal (through anoxic denitrification) depending on the mode of operation. In contrast, the submerged aeration systems function similar to conventional nitrifying activated sludge systems when operated without bioaugmentation. However, when bioaugmentation is initiated before nitrification develops, BOD is removed and the nitrification reaction is inhibited, thus producing an effluent low in biodegradable organic substrate yet high in ammonia. Alternately, if a nitrifying culture is established before bioaugmentation, there is evidence that aerobic denitrification processes will occur, resulting in an effluent low in BOD and inorganic nitrogen. Similar transformation and removal dynamics are expected for other wastewater constituents.

The application of these effluents to soil lysimeters will improve our understanding of the fate of wastewater constituents under different treatment scenarios and in the soil. The results will be useful for decision makers contemplating the appropriate use of onsite wastewater treatment systems for protection of public and environmental health.

Professional Presentations

Leverenz, H.L. The use of pretreatment technologies for the removal of wastewater constituents, National Symposium on Individual and Small Community Sewage Systems (ASAE), Sacramento, CA, March 21-24, 2004.

Student Training

Gina Choi, undergraduate; Civil and Environmental Engineering, UC Davis

Ian Maki, undergraduate; Civil and Environmental Engineering, UC Davis

Erin Onieda, undergraduate; Civil and Environmental Engineering, UC Davis

Olivia Virgadamo, graduate, M.S.; Civil and Environmental Engineering, UC Davis

HsinYing Liu, graduate, Ph.D.; Civil and Environmental Engineering, UC Davis

Harold Leverenz, graduate, Ph.D.; Civil and Environmental Engineering, UC Davis

Additional Funding

The following equipment has been donated (values estimated) for the purpose of conducting the research:

- → Four septic tanks, $5,000 (Delta Precast & Jensen Precast)
- → Three biofilm reactors, $6,000 (Orenco Systems Inc.)
- → Two aeration systems, $4,000 (Pirana Inc.)
- → Six soil lysimeters basins, $3,000 (Orenco Systems Inc.)
- → Miscellaneous pumps, basins, control systems, supplies $10,000 (Infiltrator Systems Inc., Orenco Systems Inc., & Pirana Inc.)

Collaborative Efforts

Bioaugmentation processes will be monitored and characterized through interdepartmental collaboration with Dr. Stefan Wuertz. The collaborative work will include sequencing of bacterial DNA needed to construct molecular probes to be used for identification of relevant treatment organisms.

Images

The following images have been included

Figure 1 Diagram of high efficiency biofilm reactor used for wastewater treatment, currently under evaluation at UC Davis.

Figure 2 Diagram of submerged aerated biofilm reactor used to facilitate bioaugmentation processes in wastewater treatment, currently under evaluation at UC Davis.

Figure 3 Diagram of soil lysimeter used for assessing performance of onsite wastewater treatment processes.

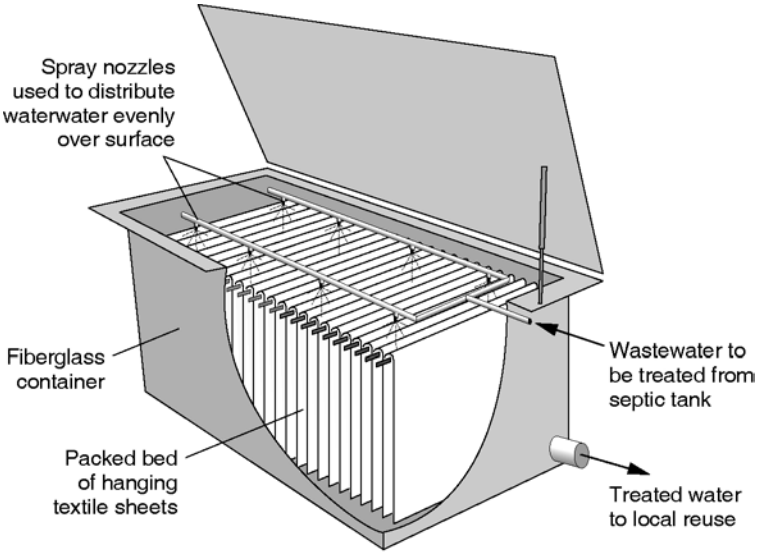

Figure 1
Diagram of high efficiency biofilm reactor used for wastewater treatment, currently under evaluation at UC Davis.

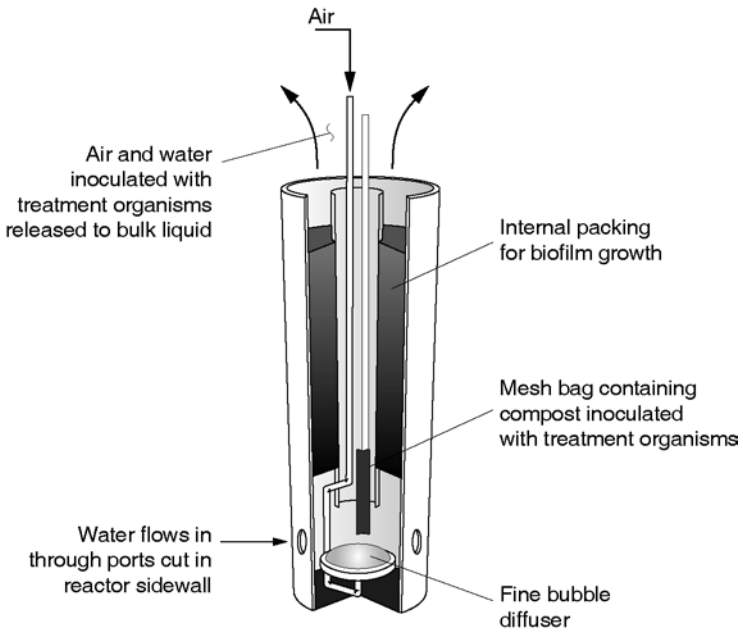

Figure 2
Diagram of submerged aerated biofilm reactor used to facilitate bioaugmentation processes in wastewater treatment, currently under evaluation at UC Davis.

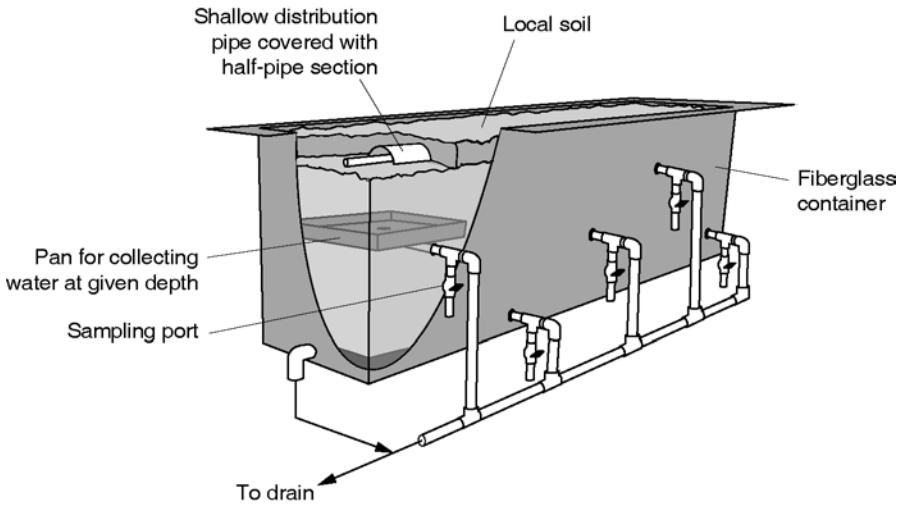

Figure 3
Diagram of soil lysimeter used for assessing performance of onsite wastewater treatment processes.

The effect of Soil Water Content on Organic Chemical Sorption During Transport Through Unsaturated Soil

Basic Information

Title:	The effect of Soil Water Content on Organic Chemical Sorption During Transport Through Unsaturated Soil
Project Number:	2002CA2B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	43
Research Category:	None
Focus Category:	Water Quality, Solute Transport, Groundwater
Descriptors:	None
Principal Investigators:	William A Jury, William T Frankenberger, Jr.

Publication

1. One in submission. None published

PROJECT SUMMARY:

A series of controlled experiments of pesticide transport at different water contents showed a significant increase in the amount of sorption occurring at lower water contents. The effect of this increased sorption is to slow down the movement of pesticide relative to both water and nonsorbing tracers (e.g. nitrates) which actually increase their speed as water content decreases in a steady water flow system. Implications of this effect were explored in modeling exercises which demonstrated two effects: pesticides will take longer to reach groundwater than previously calculated by models not including this effect; and the spatial variability of pesticide movement relative to variability of tracer and water movement will be less than previously estimated.

INFORMATION TRANSFER PROGRAM:

Presentation at Western Regional Research meeting W-188

STUDENT SUPPORT:

Partial support for Han-Song On, who did part of his dissertation research for Korea Univ. at UCR. Partial support for postdoctoral researcher Atac Tuli

NIWR – USGS STUDENT INTERNSHIP PROGRAM:

N/A

NOTABLE ACHIEVEMENTS AND AWARDS:

Provide a brief description of any especially notable achievements and awards resulting from work supported by both federal and matching funds, and by supplemental grants during the reporting period.

Perchlorate Removal in Groundwater Using Immobilized Cell-Free, Purified and Recombinant Perchlorate Reductases from the Perchlorate Respiring Bacterium, Perclace

Basic Information

Title:	Perchlorate Removal in Groundwater Using Immobilized Cell-Free, Purified and Recombinant Perchlorate Reductases from the Perchlorate Respiring Bacterium, Perclace
Project Number:	2002CA3B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	43
Research Category:	None
Focus Category:	Water Quality, Treatment, Toxic Substances
Descriptors:	None
Principal Investigators:	William T Frankenberger, Jr.

Publication

1. Articles in Refereed Scientific Journals Okeke, B.C., Giblin, T. and Frankenberger Jr. W.T., Reduction of perchlorate and nitrate by salt tolerant bacteria, Environmental Pollution, 118, 357-363, 2002.Giblin, T. and Frankenberger Jr. W.T., Perchlorate and nitrate reductase activity in the perchlorate respiring bacterium perc1ace, Microbiological Research, 156, 311 315, 2002.Losi, M.E., Giblin, T., Hosangadi, V. and Frankenberger, W.T., Biormediation of perchlorate-contaminated groundwater using a packed bed biological reactor. Bioremediation Journal, 6, 97-104, 2002.Giblin, T., Losi, M.E., Hosangadi, V. and Frankenberger, W.T., Bacterial perchlorate reduction in simulated reverse osmosis rejectate. Bioremediation Journal, 6, 105-111, 2002. Book Chapter Giblin, T., Herman, D. C. and Frankenberger, W.T., An autotrophic system for the bioremediation of perchlorate from ground water. Pp. 199-211, 1999. Perchlorate in the Environment, Plenum Press. Other Publications Okeke, B.C. and Frankenberger Jr. W.T., Molecular analysis of a perchlorate reductase from a novel perchlorate respiring bacterium, perc1ace. In Preparation.Losi, M.E., Hosangadi, V., Tietje, D. Okeke, B.C., Zuromski, R. and and Frankenberger, W.T. (2003). Field pilot testing of a dynamic susupended bed bioreactor for removal of perchlorate in ground ground water. In

preparation.

PROJECT SUMMARY

Perchlorate (ClO_4^-) is an important energetic component of solid rocket fuel. The major source of ClO_4^- pollution is the military, space program and supporting industries. Wastewater generated from the manufacturing, maintenance, and testing of solid rocket propellants can contain NH_4 perchlorate in the grams per liter concentration range. Perchlorate is recalcitrant in the environment and is potentially toxic. The California Department of Health Services adopted an action level of 4 ppb for perchlorate in potable water. Physicochemical water treatment technologies (e.g. membrane and ion-exchange systems) have been considered for ClO_4^- remediation, but they are expensive and not practical for ClO_4^- removal from ground water. Moreover, these processes produce high salt waste streams contaminated with perchlorate and require further treatment to remove residual ClO_4^-. Microbial reduction of ClO_4^- to environmentally-acceptable innocuous end products is currently an area of intense interest. Microorganisms that reduce perchlorate to chloride and molecular oxygen have been isolated. For designing an efficient biological-based ground water ClO_4^- remediation strategy, the biochemical and molecular data on the enzymatic reduction of ClO_4^- are needed. The ClO_4^- respiring organism, perc1ace when grown using either ClO_4^- or NO_3^- as a terminal electron acceptor produced ClO_4^- reductase to a significant extent. The ClO_4^- reductase activity appeared to be within the periplasmic space, with activities as high as 14, 000 $nmol^{-1}$ min^{-1} mg $protein^{-1}$, indicating that it is a soluble enzyme. A ClO_4^- reductase from cell-free extracts of perc1ace was purified 10-fold by ion-exchange and molecular exclusion fast protein liquid chromatography (FPLC). The ClO_4^- reductase catalyzed the reduction of ClO_4^- at a V_{max} and K_m of 4.8 Units mg $protein^{-1}$ and 34.5 μM, respectively. Maximal activity was recorded at 25-30^oC and pH 7.5 – 8.0. Perc1ace ClO_4^- reductase is a dimer with molecular masses of 35.07 kDa and 75.1 kDa determined by SDS-PAGE. Matrix-Assisted Laser Desorption Ionization-Time of Flight/Mass Spectrometry (MALDI-TOF/MS) analysis of the 35 kDa protein revealed several tryptic peptides (Fig. 1). To study the genetic determinants of ClO_4^- reductase, the amino terminal sequences of 22 tryptic peptides of the approximately 35 kDa ClO_4^- reductase subunit were obtained by electrospray mass spectrometry. GenBank Blast analysis of the amino acid sequences revealed similarity to reductases, dehydrogenases and heme proteins. In batch studies of in vitro reduction of perchlorate, perc1ace ClO_4^- reductase reduced perchlorate in water with either NADH or methyl viologen as an electron donor. Less enzyme activity was

observed with methanol and ethanol. Addition of perc1ace ClO_4^- reductase to ion-exchange (IEX) brine impacted with ClO_4^- substantially enhanced ClO_4^- removal by salt tolerant bacteria. Experiments showed that ClO_4^- reductase immobilized to Ca alginate reduced chlorate. Additional studies are focusing on: optimization of reaction conditions for perchlorate reduction by immobilized perchlorate reductases, molecular characterization of the overall genetic determinants of ClO_4^- bioreduction by perc1ace by cloning the genes using degenerate primers designed from the amino acid sequences of ClO_4^- reductase tryptic peptides and over-expression of recombinant ClO_4^- reductase. Such a recombinant enzyme available in large quantities can be immobilized and safely used for the treatment of perchlorate contaminated ground water on site. Treatment systems designed to employ cell-free enzymes catalyze the ClO_4^- reduction reaction without the production of biomass wastes. Moreover, the spent enzymes can be regenerated and reused, substantially reducing cost. Cell free perchlorate reductase immobilized on calcium alginate displayed ClO_4^- reductase activity.

STUDENT SUPPORT:

The project provided practical training for over 30 students enrolled in Environmental Science 155 through several hours of laboratory classes on “Bioremediation of perchlorate in ground water”. The project also supported in part, a post-doctoral fellow (Benedict C. Okeke) to carry out the study.

Voluntary Compliance Versus Mandatory Sanctions: A Natural Experiment in Water Quality Regulation

Basic Information

Title:	Voluntary Compliance Versus Mandatory Sanctions: A Natural Experiment in Water Quality Regulation
Project Number:	2002CA4B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	43
Research Category:	None
Focus Category:	Water Quality, Law, Institutions, and Policy, Agriculture
Descriptors:	None
Principal Investigators:	Paul Sabatier

Publication

Note: This project has been delayed, and will begin July 1, 2003 to be completed by September 30, 2003.

Coastal Northern California is home to dairy farms and other livestock operations that entail significant environmental costs. When animal wastes enter local streams, water quality is impaired in ways that can be lethal to fish and other aquatic life. Animal wastes are also implicated in the microbial contamination of local shellfish, creating a public health risk for both subsistence collectors and consumers of commercially cultivated clams and oysters. State regulators have historically pursued two alternative approaches to address these problems. The classic command-and-control approach emphasizes permitting requirements, injunctions, fines, and the threat of criminal prosecution in extreme cases. The alternative "voluntary compliance" approach emphasizes lenience for occasional or accidental violations, and asks the industry to take a leading role in monitoring and enforcing compliance. This study seeks to determine whether voluntary compliance has resulted in lax enforcement, or has actually yielded higher rates of compliance at lower cost, relative to command-and-control. To the extent that voluntary compliance is working successfully, the study identifies the most important mechanisms (education and outreach, promoting an environmental ethic, trust-building, etc.). The analysis is based on 10 years of water-quality data and an original survey of all 200 dairy and livestock producers in the study region. Recommendations are offered for improving the effectiveness and efficiency of dairy and livestock-related water quality regulation.

STUDENT SUPPORT (planned):

Christal Love, undergraduate, Environmental Policy and Planning
Chris Weible, graduate, Ecology, UC Davis

Information Transfer Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	1	3	3	4	11
Masters	5	6	7	8	26
Ph.D.	0	1	0	0	1
Post-Doc.	0	0	1	0	1
Total	6	10	11	12	39

Notable Awards and Achievements

Publications from Prior Projects