Water Resources Research Center
Annual Technical Report
FY 2004

Introduction

This report covers the period March 1, 2004 to February 29, 2005. This 39th year of the Massachusetts Water Resources Research Center (WRRC) was another year of transition. A new director for WRRC, Dr. Sarah Dorner, arrived in January, 2005, taking over from the interim director, Dr. David Reckhow.

In October, 2004, the MA WRRC organized the Second Annual WRRC Conference Water Resources in the Northeast: Emerging Issues. The conference involved many academic departments at UMass-Amherst, and other Massachusetts academic institutions. The conference was attended by 177 academics, agency personnel, NGO staff, University students and interested citizens and deemed a success by all participants.

Two innovative research projects continued this year: Potential Movement of Pesticides Related with Dissolved Organic Matter from Organic Fertilizer Application on Turf by Dr. Baoshan Xing of UMass-Amherst Dept of Plant and Soil Sciences, and Copper Removal by Biofilms, by Dr. Xiaoqi Zhang of UMass-Lowells Dept. of Civil and Environmental Engineering. Dr. Stephen Mabee of UMass-Amhersts Dept. of Geosciences began work on a 104G USGS grant to look at A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management.

The Centers long-term commitment to citizen involvement in scientifically-credible watershed monitoring carried on through several projects: the Massachusetts Water Watch Partnership, the Acid Rain Monitoring Project, and continued collaboration with UMass Extension on a stream continuity project. New this year was the cooperation with the Mechanical Engineering Department at UMass Amherst on a Non-Point Source grant to develop a Clearinghouse for innovative stormwater Best management Practices in Massachusetts.

Research Program

Copper Removal by Biofilms

Basic Information

Title:	Copper Removal by Biofilms
Project Number:	2003MA8B
Start Date:	3/1/2003
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	5th
Research Category:	Not Applicable
Focus Category:	Treatment, Waste Water, Water Quality
Descriptors:	Treatment, toxic substances, water quality, wastewater.
Principal Investigators:	Xiaoqi (Jackie) Zhang, Xiaoqi (Jackie) Zhang

Publication

1. Brussee, K., X. Zhang, and J. Rooney-Varga, 2005 Examination of Cellular Response of Biofilms to Copper Contamination. 3rd Annual Water Resources Conference. Amherst, MA. (Submitted)
2. Brussee, K. and X. Zhang, 2005, Copper Removal by Biofilms, Abstract for the University of Massachusetts Lowell 8th Annual Student Research Symposium.
3. Martinez, K, K. Brussee, and X. Zhang, 2005, Adaptability of Biofilm Exposed to Copper. Abstracts for the University of Massachusetts Lowell 8th Annual Student Research Symposium.
4. Brussee, K. and X. Zhang, 2004, Examination of Cellular Response of Biofilms to Copper Contamination. 2nd Annual Water Resources Conference, Amherst, MA.

Copper Removal by Biofilms

Summary

Title:	Copper Removal by Biofilms
Project Number:	
Start Date:	9/1/2003
End Date:	8/31/2005 (no-cost extension)
Research Category:	Water quality
Focus Category:	Treatment, toxic substances, water quality, wastewater.
Principal Investigators:	Xiaoqi Zhang

The reporting period is March 1, 2004 through February 28, 2005.

Problems and Research Objectives

Heavy metal contamination is of growing concern nationwide because of the numerous health risks to animals and humans. Among the five pollutants of primary concern to MWRA's Toxic Reduction and Control division in Massachusetts, three are heavy metals (i.e. Hg, Cu, and Pb, http://www.mwra.state.ma.us/sewer/html/regs2.htm). Some of the heavy metal contamination comes from agriculture and sewage disposal, although most come from industrial sources, including electroplating plants, mining, nuclear and electronics industries, metal finishing operations, tanneries, and industrial processes utilizing metals as catalysts. Since most of the heavy metal laden effluent will ultimately reach sewerage systems via direct discharge or urban runoff, it is important to remove heavy metals during wastewater treatment processes to reduce the potential harmful effects to ecosystems and public health. In Massachusetts, The Clean Water Act requires that businesses and industries that discharge into the sewerage treatment plants be regulated through an industrial pretreatment program and the discharge limit is set by the local wastewater treatment plant (WWTP). For copper, the state average local limit is 2.187 mg/l (with the maximum being 27.6 mg/l). Such program has greatly reduced the burden of local sewerage treatment plants who usually don't have the capability of handling high concentration industrial pollutants. Wastewater treated by municipal/industrial wastewater treatment plants is usually discharged into local surface water. Although many municipal/industrial wastewater treatment plants can meet the discharge limit set by DEP/EPA, some still have difficulty in meeting the copper discharge limit. Therefore there is an urgent need for an effective treatment technology to remove copper during the wastewater treatment process to meet the ever more stringent discharge limit (6.2 µg/l for copper discharge to Nashua River).

It is hypothesized that microorganisms produce negatively charged extracellular polymeric substances which can sorb positively charged copper. The objective of this research is to evaluate the effectiveness of a biofilm system in treating heavy metal containing wastewater, and determine the cellular response to copper contamination.

Methodology

Two laboratory scale biofilm reactors (Biosurface Technologies, Corp. Jacketed Model 1120LJ) (Figure 1) were used to generate biofilm growth on removable clear polycarbonate slides by seeding the reactor with activated sludge and introducing an influent with a controlled synthetic wastewater and copper concentrations.

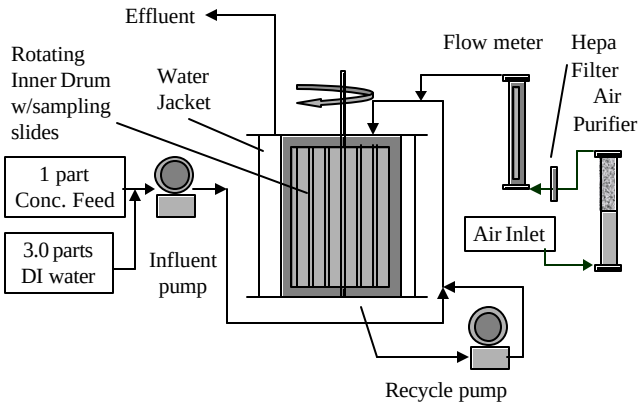

Figure 1. Experimental Flow Chart of Biofilm Reactor.

Influent Design: The synthetic wastewater is introduced to the reactor using one pump (Cole Parmer No. 7553-80) with two pump heads (Cole Parmer, Masterflex No. 77200-60). One pump head utilizes Manostat 1/16th inch tygon silicone tubing to transport the concentrated feed, the other 1/8th inch tubing to transport DI water. The two lines are joined to produce an influent with a ratio of approximately 3.0 mL of DI water to 1 mL of concentrated feed. The influent flow rate to the reactor is being maintained at 8.5 mL/min producing 106 minutes of hydraulic retention time.

Table 1. Desired influent concentrations (Zhang et al., 1999)

Organics	Influent conc. (mg/L)	Inorganics	Influent conc. (mg/L)
beef extract	41.76	NH_4Cl	1.67
yeast extract	45.93	$NaHCO_3$	156.44
peptone	41.76	K_2HPO_4	18.37
glucose	29.48	KH_2PO_4	7.11
		$MgSO_4 \cdot 7H_20$	18.37
		$FeCl_2 \cdot 4H_20$	0.25
		$CaCl_2 \cdot 2H_20$	24.56
		$NH_2 \cdot CO \cdot NH_2$	29.48
		$Na_2HPO_4.7H_2O$	27.56

A fresh twenty liters of synthetic wastewater measured by chemical oxygen demand (COD) of ~150 mg/L is prepared weekly and fed into the reactors. (see Table 1 for the feed composition). The organics (except urea) and approximately eighteen liters of DI water are autoclaved to prevent the feed from fouling (fouling has been shown to reduce the influent COD concentration, pH and ratio of free to total copper). The inorganics, urea, and copper are added once the autoclaved water has cooled and is then placed on a stir plate and hooked up to the influent pump.

Influent/Effluent Parameters: For each new twenty liters of feed, the COD concentration, pH, total copper and free copper concentration (Hach method 8143) of the influent are measured three times a week. The COD concentration, pH, total copper and free copper concentrations are also determined for the effluent on the same schedule as the influent.

Biofilm Sampling: Once the reactor has reached a pseudo-steady state condition indicated by the constant effluent COD concentration (~25 mg/L, within approximately two weeks of forward flow), and the biofilm growth is substantial enough for sampling, biofilm is scraped from one or two of the sampling slides for biofilm analysis and EPS extraction. For each sampling, the surface charge (Morgan et al., 1990), and total and free copper concentrations of the biofilm are determined (Hach method 8143). Total Solids (TS) (APHA, 1998) are determined for the biofilm to represent the total biomass of the biofilm.

EPS Extraction: Biofilm EPS is extracted according to the steaming procedure described in Zhang et al. (1999). EPS is quantified by measuring polysaccharides content (Dubois et al, 1956) and protein content (Bradford, 1976). Figure 2 shows the variety of analyses that are performed on the biofilm samples, and EPS extraction procedure and its measurement.

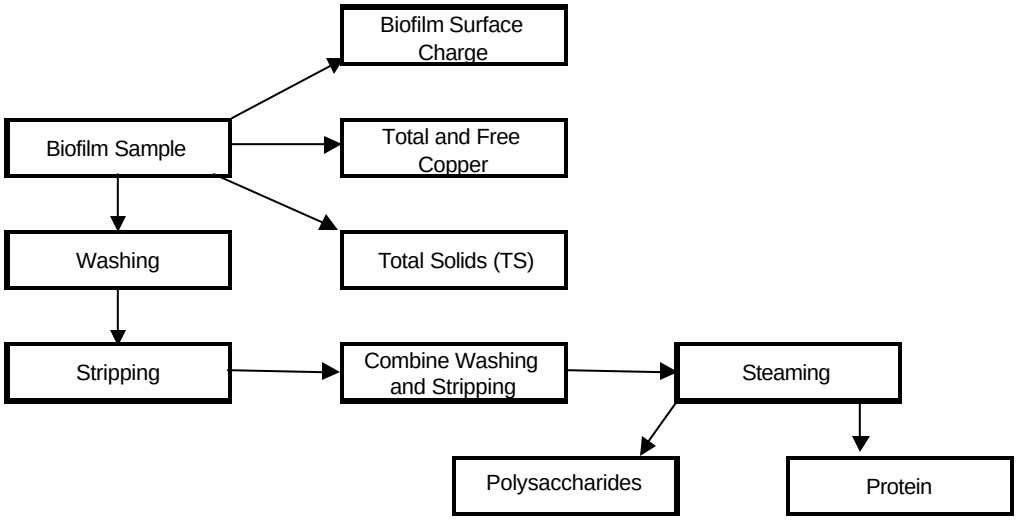

Figure 2. Flowchart of Biofilm and EPS Analyses.

Principal Findings and Significance

During this reporting period, one reactor of 0ppb Cu2+ and one reactor of 250ppb Cu^{2+} were studied.

Reactor Running Conditions: For both reactors, the COD of the synthetic wastewater influent was maintained at 150 mg/L, and the COD in the effluent reached 20-25 mg/L, indicating ~85% organics removal (Figure 3). pH in the influent was maintained at 8.0; pH in the effluent was at 7.2 (Figure 4).

Copper Removal: The total influent copper concentration was maintained at 254 (± 19) ppb. The free copper concentration of the influent was 164 (± 6) ppb and the effluent 110 (± 15) ppb. Although only 33% of the free copper was removed from the influent, either by sorption or forming complexes (Figure 5), the result suggests that a biofilm system could be used as a pretreatment for wastewater contaminated with higher copper concentration. The toxicity of copper mainly comes from free copper, therefore, this biofilm reactor is effective to a certain degree in removing the free copper and reducing copper toxicity.

Cellular Response: Under the reactor conditions of 0ppb copper, EPS-polysaccharide concentrations averaged 11.54mg/g TS, which was only slightly lower than the concentration found in the biofilm exposed to 200ppb copper (13.41mg/g TS). A significant difference was observed between the EPS-protein concentrations of the two biofilms. The EPS-protein concentration for the biofilm exposed to no copper was determined to average approximately 5.99mg/g TS, consistent with the previous finding by Ramasamy and Zhang (2004). However, the biofilm grown under 200ppb copper produced more than double that concentration (14.46mg/g TS). This may be correlated with the significant differences observed in the surface charge of each biofilm. The biofilm grown under 0ppb copper conditions developed an average negative surface charge value of –0.17µequiv/g TS. This value was found to be half the surface charge value observed by the biofilm that was produced under 200ppb copper (-0.32µequiv/g

TS). The results indicate that cells produced more proteins with negative charges as a form of cellular response to copper contamination.

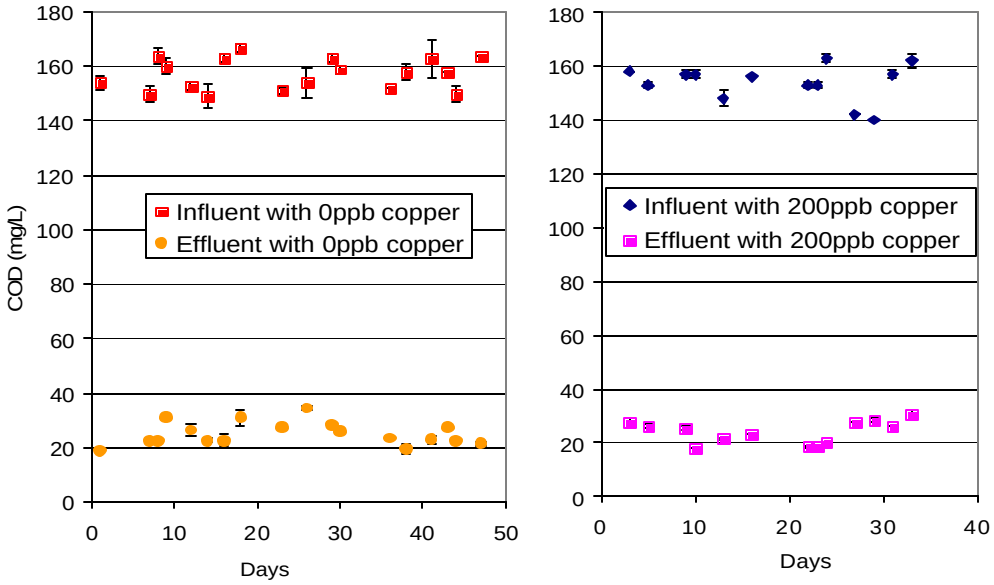

Figure 3. Reactor Running Conditions - COD

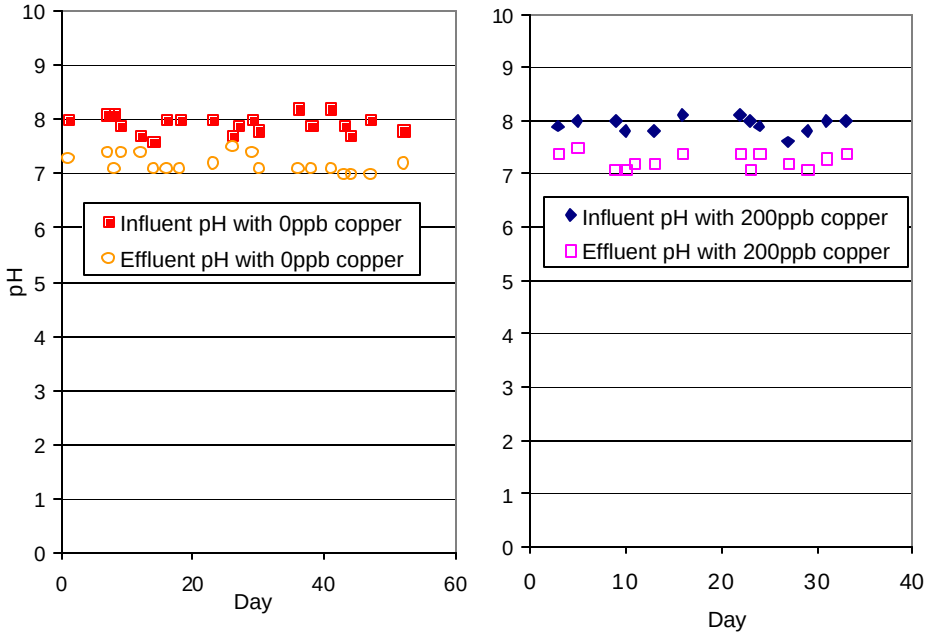

Figure 4. Reactor Running Conditions – pH

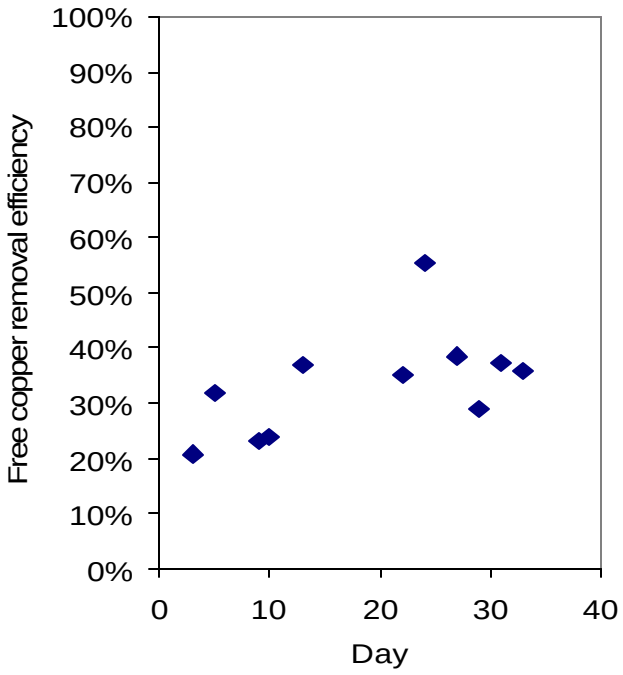

Figure 5. Free Copper Removal Efficiency of 250 ppb Copper Reactor

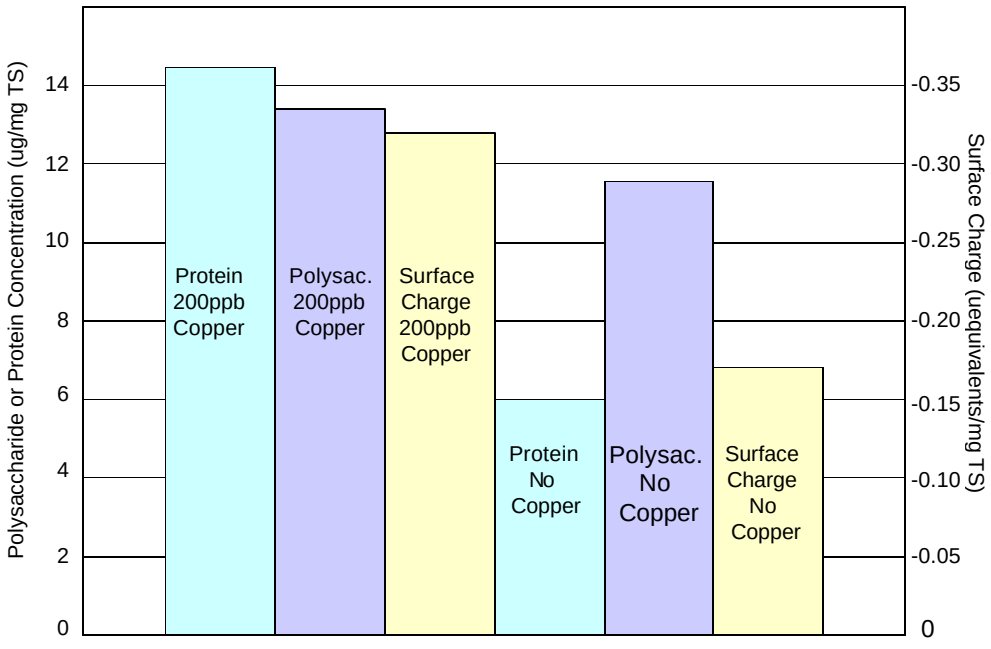

Figure 6. Biofilm Cellular Response to Copper Contamination

Microbial Community: Preliminary molecular analysis of the bacterial communities in both copper-free and copper-exposed biofilms revealed qualitative and semi-quantitative differences in their community compositions. These results indicate that exposure to 250 ppb copper selects for specific microbial populations that are able to tolerate this stress and that may contribute to its remediation.

Work in Progress

Cells may respond differently to different level of copper concentrations. Currently the biofilm exposed to 100ppb and 300ppb Cu^{2+} are being examined, the free copper removal efficiency, and their surface charge, EPS protein and polysaccharide concentrations compared to further determine the cellular response of biofilms to copper contamination.

References

American Public Health Association; American Water Works Association; Water Environment Federation (1998) *Standard Methods for the Examination of Water and Wastewater*. 20th ed., Washington, D.C.

Bradford, M. M. (1976) A rapid and sensitive method for the quantification of microgram quantities of protein utilizing the principle of protein-dye binding. *Analyt. Biochem.* **72**, 248-54.

Dubois M., Gilles K. A., Hamilton J. K., Rebers P. A. (1956) Colorimetric method for determination of sugars and related substances. *Analyt. Chemistry* **28**, 350-356.

Morgan, J.W., Forster, C.F., Evison, L. (1990) Comparative study of the nature of exopolymers extracted from anaerobic and activated sludges. *Wat. Res*. **24** (6), 743-750.

Ramasamy, P. and Zhang, X. (2004) Effects of shear stress on the secretion of extracellular polymeric substances in biofilms. Env. Eng. Sci. (In preparation)

Zhang, X., Bishop, P. L., Kinkle, B. K. (1999) Comparison of extraction methods for quantifying extracellular polymers in biofilms. *Wat. Sci. Tech*. **39,** 211-218.

Publications

Water Resources Research Institute Annual Report (this report)

Brussee, K., Zhang, X., and Rooney-Varga, J. (2005) Examination of Cellular Response of Biofilms to Copper Contamination. 3rd Annual Water Resources Conference. Amherst, MA. (Submitted)

Brussee, K. and Zhang, X. (2005) Copper Removal by Biofilms. Abstract for the University of Massachusetts Lowell 8th Annual Student Research Symposium.

Martinez, K, Brussee, K. and Zhang, X. (2005) Adaptability of Biofilm Exposed to Copper.

Abstracts for the University of Massachusetts Lowell 8th Annual Student Research Symposium.

Brussee, K. and Zhang, X., (2004) Examination of Cellular Response of Biofilms to Copper Contamination. 2rd Annual Water Resources Conference. Amherst, MA.

Students Supported (number and level)

One Master's student (Kevin Brussee) is being financially supported.
One work study female undergraduate student (Kely Martinez) is conducting research for this project.

Future Funding

The PI is actively seeking funding from NSF to continue research on this topic.

Potential Movement of Pesticides Related to Dissolved Organic Matter from Organic Fertilizer Application on Turf

Basic Information

Title:	Potential Movement of Pesticides Related to Dissolved Organic Matter from Organic Fertilizer Application on Turf
Project Number:	2003MA9B
Start Date:	3/1/2003
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	1st
Research Category:	Water Quality
Focus Category:	Water Quality, Groundwater, Solute Transport
Descriptors:	Dissolved organic matter (DOM); Sorption; Organic contaminants
Principal Investigators:	Baoshan Xing, William Torello

Publication

1. Li, K., B. Xing, and W.A. Torello, 2005, Effect of organic fertilizers derived dissolved organic matter on pesticide sorption and leaching. Environ. Pollut. 134: 187-194.
2. Heymann, K., H. Mashayekhi, and B. Xing, 2005, Spectroscopic analysis of sequentially extracted humic acid from compost, Spectroscopy Letters, (in press).
3. Li, K., 2004, Evaluation of organic turfgrass management and its environmental impact by dissolved organic matter, Ph.D. Dissertation, University of Massachusetts, Amherst, MA, 101pp.

Title: Potential Movement of Pesticides Related with Dissolved Organic Matter from Organic Fertilizer Application on Turf

Start Date: May 1, 2004
End Date: February 28, 2006

Research Category: Water Quality

Focus Category: Nonpoint Pollution; Surface Water; Water Quality;

Descriptors: Dissolved organic matter (DOM); Sorption; Organic contaminants

Principal Investigator: Baoshan Xing

Project Description: Incorporation of organic fertilizers/amendments including composts has been a popular strategy for golf course turfgrass management. Dissolved organic matter (DOM) derived from these organic materials may, however, facilitate organic chemical movement through soils. DOM was extracted from two commercial organic fertilizers and used for a column study. In this column study, we used chlorpyrifos and USGA (United States Golf Association) sand. We observed that DOM reduced the retention of chlorpyrifos in the column as compared with the 0.01 M solution without DOM. We also characterized compost materials using sequential alkaline extraction and spectroscopic techniques (e.g., FTIR and NMR). Significant structural variations among the extracted humic acid (HA) fractions and the original compost were observed. A decrease in the atomic C/H ratio and increase in the atomic C/O ratio among these HA fractions represented an increase in aliphaticity in conjunction with a decrease in polarity and aromaticity, confirmed by spectroscopic data.

Publications:

Li, K., B. Xing, and W.A. Torello. 2005. Effect of organic fertilizers derived dissolved organic matter on pesticide sorption and leaching. Environ. Pollut. 134: 187-194.

Heymann, K., H. Mashayekhi, and B. Xing. 2005. Spectroscopic analysis of sequentially extracted humic acid from compost. Spectroscopy Letters, (in press).

Li, K. 2004. Evaluation of organic turfgrass management and its environmental impact by dissolved organic matter. Ph.D. dissertation, University of Massachusetts at Amherst.

Students Supported:

One undergraduate student
One Ph.D. student

Acid Rain Monitoring Project - Phase IV

Basic Information

Title:	Acid Rain Monitoring Project - Phase IV
Project Number:	2004MA29B
Start Date:	7/1/2003
End Date:	6/30/2005
Funding Source:	104B
Congressional District:	1st
Research Category:	Water Quality
Focus Category:	Water Quality, Acid Deposition, Surface Water
Descriptors:	
Principal Investigators:	David A. Reckhow, Paul Joseph Godfrey, Marie-Francoise Walk

Publication

The Acid Rain Monitoring project continued for the 5th consecutive year after an 8 year hiatus preceded by 10 years of consecutive sampling. About 150 sites (mostly streams) were sampled by volunteer collectors and tested for pH and alkalinity by volunteer labs. Of those 100, 26 long-term sites were analyzed for the full suite of major cations and anions. The data from 1983 to 1993 were previously analyzed for trends relevant to acid rain control. With sufficient new data on lakes and streams collected over the past 4 years, changes resulting from passage of state and federal clean air act revisions can be evaluated. These analyses are in process and should provide important evidence in the ongoing debate about clean air standards.

The more than 43,000 records of water chemistry for Massachusetts' lakes and streams, covering 1983-2004 have been made available on the world wide web in a searchable and downloadable form so that additional data analyses specific to the user may be conducted.

Also, a 1986 publication of the WRRC called Acid Rain in Massachusetts is being updated to include the past two decades, the results of the trend analysis, and their relevance to the current national debate on clean air act standards.

A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management

Basic Information

Title:	A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management
Project Number:	2003MA19G
Start Date:	9/30/2004
End Date:	9/29/2006
Funding Source:	104G
Congressional District:	1st District of MA
Research Category:	Ground-water Flow and Transport
Focus Category:	Water Supply, Groundwater, Water Quantity
Descriptors:	fracture characterization, domain analysis, well yield, fractured rock aquifers, groundwater availability, groundwater mapping, borehole geophysics
Principal Investigators:	Stephen B. Mabee, Michele Cooke

Publication

Title: A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management

Start Date: 9/30/2004 (No cost extension granted September 2004)

End Date: 9/29/2007

Research Category: Groundwater Flow

Focus Category: Water supply, Groundwater, Water Quantity

Descriptors: fracture characterization, domain analysis, well yield, fractured rock aquifers, groundwater availability, groundwater mapping, borehole geophysics

PI's: Stephen B. Mabee
State Geologist
University of Massachusetts
Phone: 413-545-4814

Michele Cooke
University of Massachusetts

Project Description

Problem Statement

The use of fractured-bedrock aquifers to meet private, public and commercial water supply needs is increasing in the New England region. Municipalities and water suppliers are finding it increasingly difficult to locate and develop water supplies in overburden aquifers because of contamination and a lack of suitable sites. In addition, recent droughts in the northeast have forced many communities and homeowners to drill new wells. As a result, water suppliers are going deeper into bedrock aquifers. Yet information on the factors that influence the availability and recharge characteristics of fractured bedrock aquifers in highly deformed crystalline metamorphic rocks is limited.

The availability of water in fractured rock aquifers is particularly critical in New England because growth and development along the coast, major transportation corridors and in rural communities adjacent to large metropolitan areas is rampant. For example, the I-495 corridor in Massachusetts, a circumferential highway 30 miles west of Boston, has become the focus of recent growth. Professional office buildings, research and development parks associated with the

computer industry, warehouses and light industry are springing up along this corridor, as are housing and condominium developments. Municipalities and water suppliers are simply unprepared for the onslaught of development and need help in understanding the complex dynamics of the ground water system.

Sustaining and managing ground water resources in fractured bedrock requires an evaluation of 1) the availability of water, 2) the source and vulnerability of recharge to water supply wells and 3) the impact of water withdrawals from the bedrock on streams, wetlands and unconsolidated aquifer systems that overlie the bedrock. These evaluations all require basic information on the physical characteristics of the ground water system.

Objectives

The objectives of this project are to gather regional bedrock characteristics that relate to the occurrence and movement of ground water in bedrock and use this information to begin constructing regional conceptual models of the fractured-rock aquifers in the Nashoba terrane in Massachusetts. The approach utilizes existing information augmented by the collection of low-cost field data to develop regional conceptual models of the ground water flow system. Water managers can then use these conceptual models as an initial framework for formulating an understanding of bedrock flow behavior and recharge characteristics.

Specific tasks of this project involve: 1) Fracture Characterization and Domain Analysis - collection and synthesis of fracture characterization data over the region and mapping of the spatial distribution (domain analysis) of fracture sets and their characteristics, 2) Compilation and Analysis of Existing Well Data - compilation and statistical analysis, including variography, of available well data to link spatial continuity of well yields to characteristics of the fractured rock system, 3) Borehole Geophysics - collection of optical and acoustic televiewer data from selected boreholes to verify sheeting joints, 4) Compilation of Regional Litho-Group Map - development of a mapping classification system that uses the notion of "litho groups" to characterize bedrock units in terms of their fracture characteristics, physical properties and geologic setting (eg., overburden type and thickness) and 5) Conceptual Model - preparation of a qualitative conceptual model of ground water flow behavior in each litho group category.

Relationship of Project to USGS and Other Activities

This project is part of a much larger, more comprehensive study being conducted by the USGS WRD Northborough office on the Geohydrology of the Nashoba Terrain, Massachusetts. This larger scale project involves the collection of data at three scales: regional, quadrangle and the local well-field scale. Recent work by the USGS in Connecticut and New Hampshire indicates that an understanding of ground water occurrence and movement in fractured rock aquifers can be made by combining the results of 1) fracture, geologic, well, and geophysical analyses performed at the regional level, 2) detailed mapping of bedrock lithology and physical characteristics that affect water occurrence and flow at the quadrangle scale, and 3) hydrogeologic and geophysical investigations at the well-field scale. This larger scale project is a joint effort that involves the participation of USGS scientists from the Water Resources Discipline, USGS mappers from the BRASS (Bedrock Regional Aquifer Systematics Study)

program, the Office of the Massachusetts State Geologist, and University of Massachusetts scientists (this project). Table 1 describes the tasks that each agency will perform and shows how the work will be coordinated.

Table 1. Coordination Plan and Approximate Timetable

Task	Activity	Timetable	Responsible Party
Existing Data (Regional Scale)	Base map	2003	USGS[1]
	Geologic map	2003	USGS
	Imagery	2003	USGS
	Fracture data/analysis	underway	This Project[2]
	Existing well data/analysis	underway	This Project
	Add'l well data in field	2005	USGS
	Borehole fracture data	2005	This Project/USGS
	Litho-group map	2006	This Project
Geologic & Fracture Data (Quadrangle Scale)	Map Quad #1-Grafton	Near completion	USGS BRASS[3]
	Map Quad #2-Marlboro	completed	State Geologist[4]
	Map Quad #3-to be deter.	2005	USGS BRASS[3]
	Map Quad #4-Hudson	completed	State Geologist[4]
Conceptual Model Devel.		2006	This Project/USGS
Test and Verify Model (Well Field Scale)		2006	USGS
Prepare and Publish Reports		2006/2007	This Project/USGS

[1] Start date of USGS cooperative project is March 2003, Bruce Hansen, USGS

[2] Start date of this project is September 30, 2004 (no cost extension granted)

[3] USGS BRASS = Bedrock Regional Aquifer Systematics Study project, Greg Walsh, USGS, began mapping in summer 2004; selection of a second quadrangle will be made spring 2005 and mapping commences in summer 2005

[4] State Geologist – Mapping funded by the STATEMAP component of the National Cooperative Geologic Mapping Program, Marlboro completed in June 2004, Hudson preliminary map completed in June 2005, Ayer quadrangle underway in summer 2005.

Work Accomplished on *This Project* to Date

Alex Manda began working on this project in September 2004. Alex received his undergraduate degree in geology from Cardiff University in 2001 and finished his M.S. degree at Florida International University in August 2004. He passed his Ph.D. comprehensive exams at the University of Massachusetts in February 2005.

Work completed during the period September 1, 2004 and February 28, 2005.

1. Acquired Ground Water Site Inventory (GWSI) and pumping test data from the USGS (Task 2).
2. Assembled and analyzed well database using Geographic Information Systems (Task 2)*.
3. Created Nashoba Terrane base maps in preparation for field mapping in Summer 2005.

4. Delineated areas in mapping region from which to collect fracture characterization and rock characteristics data.
5. Currently investigating spatial continuity of water well yields from the bedrock aquifer using geostatistics (Task 2).

On June 1, 2005 will commence field mapping and fracture characterization data collection with field assistant Steve Hubbs (Task 1). Training sessions for fracture data collection are underway. Will continue to investigate spatial continuity of well yield in the Nashoba terrane and will plan a work session with Larry Drew (USGS) to evaluate variography and geostatistical data analyses. Plan to participate in the Massachusetts Water Resources Research Conference in October 2005 to present preliminary results.

***Summary of Preliminary Results of Well Inventory Analysis**

The GWSI data set provided 586 bedrock wells with well yield information collected from the ~ 600 square mile Nashoba Terrane. The data set is still, however, incomplete as other attributes such as drawdown, specific capacity and duration of pumping tests were either recorded for only a few wells or were not recorded at all. The GWSI data set will be augmented with other well data collected as part of quadrangle-scale mapping by the State Geologist in the Hudson, Marlborough and Ayer quadrangles.

The following attributes were investigated to verify how they affected well yield: Formation, overburden type, overburden thickness, topography, water use, construction method and depth of penetration of wells into bedrock.

The most productive formation was the Tadmuck Brook Schist with a median well yield of 0.08 gpm/ft. The least productive formation was the Marlboro with a median yield of 0.04 gpm/ft.

Overburden type does not appear to affect well yield although overburden thickness does. Wells that are located in areas that have an overburden thickness of between 10 and 100 feet provide the highest median yields. The highest median yield (0.09gpm/ft) is observed in wells that have an overburden thickness of between 30 and 50 feet.

Wells in upland draws, flats and terraces are the highest yielding wells with median yields of 0.11, 0.11 and 0.08 gpm/ft respectively. The majority of wells in the data set were located on hillsides, and these had the lowest median yield of 0.05 gpm/ft.

Wells constructed for provision of water to industrial and institutional facilities were the highest yielding wells with median yields of 0.14 and 0.10 gpm/ft. However, most of the wells in the database were constructed for domestic purposes and, as such, the domestic wells generally have lower yields.

There were predominantly three methods used to construct the wells in the Nashoba Terrane: Cable tool, Air Percussion and Air Rotary. Of these, cable tool and air percussion construction methods produced the highest median yield of 0.07gpm/ft.

High yields are observed where wells are drilled into bedrock between depths of penetration of 10 and 100 feet. Wells that penetrate bedrock between 10 and 30 feet give a median yield of 0.09 gpm/ft. As the depth of penetration increases to 30 – 50 feet the median yield increases to 0.13 gpm/ft.

Work Accomplished by Collaborators (Table 1)

USGS – The USGS WRD Northborough office has acquired some funds to continue on this project. A meeting will be held this spring to determine data needs for the project.

Office of the Massachusetts State Geologist – The office of the Massachusetts State Geologist has contributed in the following way using funds supplied by the National Cooperative Geologic Mapping STATEMAP program.

1. A preliminary bedrock geologic map and a fracture characterization map have been prepared for the Hudson quadrangle. These maps provide detailed lithologic and fracture characterization data as well as information on the distribution of permeable overburden deposits at the quadrangle scale. These data will be used as a test for the regional scale litho-group maps to be prepared under this project.
2. A well database consisting of over 1400 wells has been assembled for the Hudson quadrangle. This includes six towns all located within the project area. These data will be used as part of the well inventory for the project.
3. During the summer of 2005, bedrock and fracture characterization data will be collected for the Ayer quadrangle. A well database is also being prepared for the towns located in this quadrangle.

USGS BRASS Program – Greg Walsh from the USGS BRASS program is completing bedrock and fracture mapping in the Grafton quadrangle. This will provide detailed lithologic and fracture characterization data for a third quadrangle within the project area. The State Geologist and BRASS are currently in the process of selecting a second quadrangle that will support this project. Mapping for this second project should begin in summer 2005.

Summary

Alex Manda, who will perform the majority of the regional-scale work for this project, has begun work in earnest. Initial well data has been collected and general statistics performed on the data. Existing well-field pumping test and borehole geophysical data have been acquired from the USGS. Fracture data collection will commence in summer 2005. Collection of additional well-field scale pumping test data, borehole geophysical data, well inventory information and quadrangle-scale geologic and fracture mapping being performed by project collaborators is well underway and will continue through 2005.

Information Transfer Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	5	0	0	0	5
Masters	1	0	0	0	1
Ph.D.	1	1	0	0	2
Post-Doc.	0	0	0	0	0
Total	7	1	0	0	8

Notable Awards and Achievements

Publications from Prior Projects

None