Environmental Resources Research Institute
Annual Technical Report
FY 2001

Introduction

The following report presents the FY 2001 program of research and educational outreach projects funded through the Pennsylvania Water Resources Research Program for the period March 1 2001 through February 28, 2002. A project supported with base grant funds was used to develop an Extension circular entitled Passive Treatment for Acid Waters in Pennsylvania. The guide was intended for use by the large number of watershed groups in Pennsylvania that are getting involved with remediation of stream acidity due to past coal mining and acid rain. In addition to formal projects, the Pennsylvania Water Resources Research Center has also supported publication of several issues of a newsletter, development of a water center website, dissemination of water resources information to a large number of individual citizens, and operation of a inorganic water quality analysis laboratory to support research at Penn State.

Research Program

The research projects all dealt with water quality problems important to the state and region. Two completed research projects were funded through the water center base grant (P. L. 98-242 Section 104B). One on-going research project in Pennsylvania was funded through the national competitive grants program (Section 104G) during FY 2001. The first base-funded research project (2001 PA 2881) dealt with improving methods for water and wastewater treatment by using coagulants in concert with micro-filtration. Coagulants improved the effectiveness of micro-filtration that is being used more commonly to meet enhanced water quality standards. Another completed research project (2001 PA 6B), which was continued from the prior year and supported with base funds, addressed models for the impact of rapidly-expanding recreational boating, such as jet skis, on disturbance of bottom sediments in lakes and streams. The model can be used to predict increases in turbidity from recreational boating and develop guidelines for managing boat traffic. The only competitive grants research project initiated during the past year in Pennsylvania (2001 PA 721G) involves development of new culture and identification techniques for the study of arsenate-reducing bacteria. Bacteria may be responsible for mobilizing arsenic in groundwater, which has been linked to human health problems from arsenicosis. In the early work on this project a new species of arsenate-reducing bacteria has been identified from sediments in the Ohio River.

In-line Coagulation for Microfiltration

Basic Information

Title:	In-line Coagulation for Microfiltration
Project Number:	2001PA2881B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Water Quality
Focus Category:	Treatment, Water Supply, Waste Water
Descriptors:	Membrane, Microfiltration, Treatment, Potable Water, Waste Water
Principal Investigators:	Brian Andrew Dempsey

Publication

1. Williams, S.G.; Wert, J.D.; and Dempsey, B.D., 2002, Small Treatment Plant Technology in the Face of New Surface Water Treatment and Disinfection Byproduct Rules in Proceedings of the American Water Works Association Annual Conference and Exposition, New Orleans, LA, June 16-20, 2002. (Note: Proceedings were published as CD-ROM without page numbers).
2. Dempsey, B.A., 2002, Coagulants and Microfiltration: from Laboratory to Design and Operation in Proceedings of the Intertech 2002 Coagulants and Flocculants, Chicago, IL, May 22-24, 2002. (Note: Proceedings were published as CD-ROM without page numbers).

PROBLEM AND RESEARCH OBJECTIVES:

Use of micron filtration for treatment of water and wastewater is growing rapidly. In many installations, operators have required the post-design application of coagulants in order to achieve the design water production rates. However, strategies for in-line coagulation / micron filtration had not been established. This project addressed the use of coagulants for micron filtration. The objectives were to determine the coagulation conditions that could result in low trans-membrane pressures (TMP), long operation between chemical in-place cleaning (CIP), and removal of contaminants such as natural organic materials.

METHODOLOGY:

The research involved bench-scale testing at Penn State and collaboration with membrane vendors and membrane users for field applications. The major independent variables for both bench-scale and pilot-scale testing were total organic carbon (TOC) concentration, coagulant type, coagulant dose, pH, zeta-potential of the resulting solids, permeate flux and other operating conditions.

A bench-scale Pall Microza microfiltration unit was used for tests on water from the Susquehanna River near Duncannon PA. The objective was to determine appropriate coagulation conditions so that membrane filtration would produce a finished water in compliance with the Enhanced Surface Water Treatment Rules, especially regarding the need to remove at lest 35% of TOC. The focus of these experiments was to determine the effect of coagulation on water quality and therefore experiments were run at the relatively low permeate flux of 50 gal/day/ft^2 (gfd). The same experimental set-up was subsequently used for other synthetic and natural waters.

In other bench-scale experiments, flat membranes were used in recirculated-batch experiments, and permeate flux was regularly increased from about 10 gfd to about 180 gfd. Various coagulation conditions were tested. The rate of increase of trans-membrane pressure (TMP) with permeate flux was used to estimate the “critical flux”, i.e. the permeate flux at which rapid fouling of the membrane occurred. Water quality was also determined for each coagulant and permeate flux condition.

Pilot-scale and full-scale field tests were performed at Duncannon PA and other locations, in collaboration with consultant and municipal partners.

PRINCIPAL FINDINGS:

Addition of coagulants improved removals of contaminants and also resulted in decreased TMP for a given permeate flux. Low solids loading was achieved through manipulation of pH as well as selection of the best coagulants for each water supply. Aluminum chlorohydrate was universally effective, while alum, ferric chloride, and polyaluminum chlorides were very effective coagulants for some waters and were poor coagulants for other waters. Coagulants were effective even when the conditions were inappropriate for conventional water treatment practices, i.e. when the zeta potential and coagulant dose prohibited formation of solid phases that could be removed by conventional clarifiers and rapid filters. Bench-scale results accurately predicted pilot-scale performance, especially for removal of contaminants such as TOC and manganese.

Application of the bench-scale results to full-scale membrane facilities resulted in decreased TMP for the design flux.

Students Supported: Young-June Choi, Environmental Engineering, Ph.D.

Presentations and Other Information Transfer Activities:

Dempsey, B.A. "Small System Compliance Technology", 2001 PA Rural Water Association Annual Conference, University Park, PA, March 29, 2001.

Choi, Y., In-line Coagulation with Micron Filtration, ACS Colloid & Surface Science Symposium, Carnegie Mellon University, June 10-13, 2001, Pittsburgh, PA.

Dempsey, B.A., Use of Coagulants with Membrane Filtration, invited presentation at Southern Ionics, Inc., October 1-2, 2001, Columbus, MS.

Dempsey, B.A. "Micron Filtration for Potable Water and Wastewater", Presented at VPI&SU, Department of Civil & Environmental Engineering, Blacksburg, VA, November 2, 2001.

Choi, Y., 'Searching for Cleaner Drinking Water: In-line Coagulation with Micron Filtration', Annual Symposium of the Penn State Center for Environmental Chemisty & Geochemistry, March 22-23, 2002, University Park, PA.

Rosatti, D., and Choi, Y., "Beneficial Reuse of Wastewater using Coagulation and Membrane Filtration", Green Design Symposium of the Penn State Center for Sustainability, April 26-27, 2002, University Park, PA.

Dempsey, B.A. Pre-Conference Workshop on Coagulants and Flocculants, *Intertech Coagulants & Flocculants 2002*, Chicago, IL, May 22, 2002.

Williams, S.G., Wert, J.D., and Dempsey, B.D. Small Treatment Plant Technology in the Face of New Surface Water Treatment and Disinfection Byproduct Rules. Am. Water Works Assn., Annual Conference & Exposition, New Orleans, LA, June 16-20, 2002.

Penn State, Department of Civil & Environmental Engineering, PhD seminar course "Membrane Science and Technology", Spring 2002.

Short course on Membranes for Small Water Systems, in preparation for the PSU-Harrisburg Center for Small Water Treatment Facilities.

Enrichment, biochemical, and molecular techniques for assessing microbial arsenic reduction

Basic Information

Title:	Enrichment, biochemical, and molecular techniques for assessing microbial arsenic reduction
Project Number:	2001PA721G
Start Date:	9/1/2001
End Date:	8/31/2003
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Water Quality, Groundwater
Descriptors:	arsenic, bacteria, enrichment culture, biochemical probes, molecular probes, arsenate reductase
Principal Investigators:	John F. Stolz

Publication

1. Stolz, J.F., P. Basu, and R.S. Oremland, 2002. Microbial transformation of elements: the case for arsenic and selenium. Int. Microbiol. 5:201-207.

PROBLEM AND RESEARCH OBJECTIVES:

Use of micron filtration for treatment of water and wastewater is growing rapidly. In many installations, operators have required the post-design application of coagulants in order to achieve the design water production rtes. However, strategies for in-line coagulation / micron filtration had not been established. This project addressed the use of coagulants for micron filtration. The objectives were to determine the coagulation conditions that could result in low trans-membrane pressures (TMP), long operation between chemical in-place cleaning (CIP), and removal of contaminants such as natural organic materials.

METHODOLOGY:

The research involved bench-scale testing at Penn State and collaboration with membrane vendors and membrane users for field applications. The major independent variables for both bench-scale and pilot-scale testing were total organic carbon (TOC) concentration, coagulant type, coagulant dose, pH, zeta-potential of the resulting solids, permeate flux and other operating conditions.

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Presentations and Other Information Transfer Activities:

Dempsey, B.A. "Small System Compliance Technology", 2001 PA Rural Water Association Annual Conference, University Park, PA, March 29, 2001.

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Choi, Y., 'Searching for Cleaner Drinking Water: In-line Coagulation with Micron Filtration', Annual Symposium of the Penn State Center for Environmental Chemisty & Geochemistry, March 22-23, 2002, University Park, PA.

Rosatti, D., and Choi, Y., "Beneficial Reuse of Wastewater using Coagulation and Membrane Filtration", Green Design Symposium of the Penn State Center for Sustainability, April 26-27, 2002, University Park, PA.

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Penn State, Department of Civil & Environmental Engineering, PhD seminar course "Membrane Science and Technology", Spring 2002.

Short course on Membranes for Small Water Systems, in preparation for the PSU-Harrisburg Center for Small Water Treatment Facilities.

Resuspension of Bottom Sediments by Recreational Watercraft

Basic Information

Title:	Resuspension of Bottom Sediments by Recreational Watercraft
Project Number:	2001PA6B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Engineering
Focus Category:	Management and Planning, Recreation, Sediments
Descriptors:	Sediment Resuspension, Recreational Conflicts, Fluid Mechanics
Principal Investigators:	David F. Hill

Publication

1. Beachler, M.M., D.F. Hill, 2002, "The hydrodynamic impacts of recreational watercraft on shallow lakes," Lake and Reservoir Management, in press.
2. Beachler, M.M., 2002, "The hydrodynamic impacts of recreational watercraft on shallow lakes," M.S. Thesis, Civil and Environmental Engineering, The Pennsylvania State University, University Park, PA, 76 pp.
3. Hill, D.F., M.M Beachler, 2002, Stirring up trouble, Engineering Penn State: The Magazine of the Penn State College of Engineering, p.15.
4. Hill, D.F., M.M. Beachler, 2001, Pleasure boat speed limits can stir up trouble in shallow lakes, Penn State University Press Release, November 9.

PROBLEM AND RESEARCH OBJECTIVES:

On our nation's waterways, one variable has been dramatically increasing in significance in recent years and that is the level of recreational boat traffic. Not only are there more boats in use, but they tend to be larger and of greater horsepower. Additionally, the emergence of personal watercraft, familiarly known as jet-skis, has yielded a new class of craft that can travel in extremely shallow waters because of their shallow drafts. The impacts of watercraft on aquatic systems occur on many levels and include, among others, pollution in the form of noise, exhaust and unburnt fuel emissions, and hydrodynamic processes such as turbulence and wake generation. While many of these effects have been well studied in the past, a detailed and thorough investigation of the hydrodynamic impacts, specifically the resuspension of fine-grained sediments, of recreational craft has not yet been undertaken.

In the current work, attention will be focused on the interaction of turbulence generated by watercraft propulsion systems with the lake bed. Restriction will be made to recreational watercraft, characterized by lengths of approximately twenty feet or less and horsepowers of less than 150. Jet-skis are also be included. Laboratory experiments and a unique field study will be carried out in order to answer the following fundamental questions: * Under what operating conditions can a boat resuspend sediment from a lake bed? * What are the relative contributions of transient events and steady-state operation to the total resuspended sediment load? * What are the relative contributions of different types of boats (e.g. inboard, outboard, jet-ski)?

METHODOLOGY:

To answer these questions, a detailed field study was conducted in the summer of 2001. The goals of the field study were to document the time-varying velocity and turbidity induced at the lake-bed by passing boats. To accomplish this, two different instruments were used. The first, a Sontek Acoustic Doppler Velocimeter (ADV), uses scattered sound waves to deduce all three components of fluid velocity in a small measurement volume. The instrument was mounted horizontally such that the measurement volume was 10 cm above the lake bed and the sampling rate was 25 Hz. The second instrument, a Downing & Associates Optical Backscatter Sensor (OBS-3), uses scattered infrared light to measure the turbidity of the water. If local sediment samples are collected, this turbidity can, in turn, be calibrated to suspended sediment concentration (SSC). The sampling volume for the OBS-3 is larger and less well defined than that of the ADV, but the instrument was mounted approximately 2.5 cm above the lake bed in order to register the entrainment of sediment from the bed itself.

A series of controlled experiments was then performed for each craft. Having selected an appropriate region (i.e. depth) of the lake to work in, a series of gates was constructed in order to guide the watercraft directly above the instrumentation. Numerous runs, at a wide range of speeds were then carried out. The gates were then set up in a different water depth and the trials were repeated.

PRINCIPAL FINDINGS AND SIGNIFICANCE:

This project yielded useful findings on several levels. At the most specific, it was demonstrated that typical recreational watercraft have the most impact, in the context of bottom stirring, when traveling at a depth-based Froude number of one. For example, in roughly 2 meters of water, boats cause the most impact when traveling around 10 miles per hour. There is, obviously, a logical variation with water depth. Boats traveling in extremely shallow water cause far greater impact than those in deeper water. For the boats studied in the current work, it was found that limited impact would occur when boats were in water deeper than 8-10 feet.

On a more general level, this study demonstrated that mathematical modeling of the flow induced by passing boats was relatively successful at reproducing the observations. The implication of this is that the model can be used to assess the potential for bottom stirring under conditions that lie outside the parameter range directly studied.

The funded work has had a significant impact to date. In addition to leading to three invitations for presentations, the work, and accompanying press releases, has led to dozens of personal requests for pre-prints and to another funded project in south-eastern Alaska.

Students Supported:
Michele Beachler, M.S., Civil & Environmental Engineering

Presentations and Other Information Transfer Activities:

Hill, D.F., 2002, "ADV measurements of planning boat prop wash in the extreme near field," presented at the Hydraulic Measurements and Experimental Methods Conference.

Hill, D.F., 2002, "The hydrodynamic impacts of recreational watercraft on shallow lakes," seminar presented at the University of Nevada at Reno.

Hill, D.F., M.M. Beachler, 2002, "The impact of boat wakes and prop wash on bottom sediments," invited key presentation at the 2002 Wisconsin Lakes Convention, Green Bay, WI.

Hill, D.F., M.M. Beachler, 2001, “The hydrodynamic impacts of recreational watercraft on shallow lakes,” invited key session presentation at the North American Lake Management Society Symposium, Madison, WI.

Information Transfer Program

Basic Information

Title:	Acid Water Mitigation Methods
Start Date:	3/1/2001
End Date:	6/30/2002
Descriptors:	Water Treatment, Water Quality, Mining, Acid Deposition
Principal Investigators:	William E. Sharpe

Publication

1. Schmidt, K.L. and W.E. Sharpe. 2002. Passive treatment methods for acid water in Pennsylvania. College Agricultural Sciences, Agric. Res. and Coop. Extension, Univ. Park, PA. 19 p.

PROBLEM AND RESEARCH OBJECTIVES

Watershed coordinators and volunteer groups need a quick, simple reference to low cost passive acid water remediation techniques.

METHODOLOGY

Prepare an educational circular on acid water remediation for watershed coordinators.

PRINCIPAL FINDINGS AND SIGNIFICANCE

The draft document has been reviewed by PA DEP personnel and a committee of Penn State faculty. It has been edited by the College of Agricultural Sciences editorial staff. Printing was completed by the end of 2002.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	0	0
Masters	2	3	0	0	5
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	3	3	0	0	6

Notable Awards and Achievements

Several noteworthy achievements resulted from the FY 2001 program. The publication "Passive treatment methods for acid water in Pennsylvania" was produced in cooperation with the College of Agricultural Sciences at Penn State for use by watershed groups to help design low cost, low maintenance facilities to treat acid waters caused by acid mine drainage and acid rain. In addition, researchers at Duquesne University have developed new methods for culturing and detecting arsenate-reducing bacteria that are believed responsible for mobilization of arsenic in water linked to endocrine disruption and severe impacts on human health.

Publications from Prior Projects