

**Missouri Water Resources Research Center  
Annual Technical Report  
FY 2007**

# Introduction

Water Resources Research Center Annual Technical Report FY 2007–2008

## WATER PROBLEMS AND ISSUES OF MISSOURI

The water problems and issues in the State of Missouri can be separated into three general areas: 1) water quality, 2) water quantity, and 3) water policy. Each of Missouri's specific problems usually requires knowledge in these three areas.

**Water Quality:** New media attention to the occurrence of pesticides in drinking water in the Midwest has raised a serious public concern over the quality of Missouri's drinking water and how it can be protected. With the large agricultural activity in the state, non–point source pollution is of major interest. Because of several hazardous waste super–fund sites, hazardous waste is still of a concern to the public. The Centers' research has been to evaluate the quality of current waste sources and improve the methods to protect them. Areas of research for the past ten years have included (but are not limited to): erosion, non–point pollution reclamation of strip mine areas, hazardous waste disposal acid precipitation, anthropogenic effects on aquatic ecosystems and wetlands.

**Water Quantity:** Missouri has a history of either inadequate amounts of rainfall, or spring floods. Because of the 1987–89 drought years and the floods of 1993 and 1995, water quantity has become a major topic of concern. Research is needed to better understand droughts and flood conditions.

**Water Policy:** Policies and program need to be formulated that will ensure continued availability of water, as new demands are placed on Missouri's water. The social and economic costs may no longer be held at acceptable levels if water becomes a major issue in cities and rural areas. Past droughts and possible lowering of the Missouri River have raised serious questions over states rights to water and priority uses. Research areas in this program have included drought planning, legal aspects, perception and values, economic analysis, recreation, land/water use policy and legislation, and long–term effects of policy decisions.

## SUMMARY OF ADVISORY COMMITTEE ACTIVITIES

The following individuals have participated in the selection and development of our 2007 research program.

### UNIVERSITY OF MISSOURI FACULTY ADVISORY COMMITTEE

1. Steven Anderson, University of Missouri–Columbia, 302 Abnr Bldg.–Soil Science, Columbia, MO. 2. Patrick Osbourne, University of Missouri–St. Louis, 224 Research Building, St. Louis, MO 63121.

### STATE OF MISSOURI ADVISORY COMMITTEE MEMBERS

1. John Schumacher, U.S. Geological Survey, 1400 Independence Road, Rolla, MO 65401. 2. Dr. Steve McIntosh, Water Resources Program, Department of Natural Resources, PO Box 176, Jefferson City, MO. 3. Cindy Wolken, Acting Section Chief, Watershed Protection Section, PO Box 176, Jefferson City, MO 65102. 4. Dr. Jack Steiert, Biology, Southwest Missouri State University, Springfield, MO. 5. Mike McKee, Resource Scientist, Department of Conservation, Columbia, MO. 6. Robert Gale, Research Chemist/Section Leader Organic Chemistry, Columbia environmental Research Center, Biological Resources Division of USGS, Columbia, MO. 7. John Ford, Environmental Specialist, Department of Natural Resources, Jefferson City, MO.

# Research Program Introduction

## RESEARCH PROGRAM

### PROGRAM GOAL AND PRIORITIES

The Missouri Water Resources Research Centers goals are 1) establish active research programs to aid in understanding and solving Missouri's and the nations, water problems; 2) provide educational opportunities in research for students with an interest in water resources and related fields, and 3) be actively dedicated to the dissemination of water related information, using all aspects of the media.

Because Missouri's economy revolves around its water resources, the director and principal investigators have worked closely with the state in addressing their problems by providing research data which are necessary in order to solve present and future water problems. Each of the research projects forwarded for regional competition has undergone a thorough evaluation process by the water Centers Advisory Committee to determine its importance in solving Missouri's and the nation's water problems.

With these goals, the Center is able to mobilize the best faculty expertise in the state to examine specific water resources problems. The Center is familiar with research needs and activities, and its goals are to help researchers avoid duplicate efforts and to serve as a link between the research community and potential users of research results such as industries, planning commissions, and state agencies.

# Development of Membrane Aerated Reactor Processes for Nitrogen and Phosphorus Removal from Wastewater

## Basic Information

<b>Title:</b>	Development of Membrane Aerated Reactor Processes for Nitrogen and Phosphorus Removal from Wastewater
<b>Project Number:</b>	2007MO70B
<b>Start Date:</b>	3/1/2007
<b>End Date:</b>	2/28/2008
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	9
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Water Quantity, Nitrate Contamination, Treatment
<b>Descriptors:</b>	None
<b>Principal Investigators:</b>	Zhiqiang Hu

## Publication

1. Liang, Z. H., Nguyen, H. Hu, Z. Q. 2008. "Nutrient removal in on-site wastewater treatment systems using membrane-aerated bioreactor techniques." Proceedings at the Missouri MWEA/AWWA 2008 Joint Annual Meeting, March 31 – April 2, 2008, Tan-Tar-A Resort, Osage Beach, Missouri.

**Development of Membrane Aerated Reactor Processes for Nitrogen and Phosphorus Removal from Wastewater**

Zhiqiang Hu

Department of Civil and Environmental Engineering  
University of Missouri, Columbia, MO 65211  
[huzh@missouri.edu](mailto:huzh@missouri.edu); (573) 884-0497

Nature, Scope and Objectives of Research

Due to the excess input of nitrogen and phosphorus into the aquatic systems, nutrient contamination is one of the serious water quality problems in the United States. In the state of Missouri, particularly, eutrophication of recreational lakes because of the nutrient enrichments continues to be a concern. Symptoms of eutrophication include low dissolved oxygen (hypoxia) in the water and the occurrence of nuisance and toxic algal blooms, which decrease the water resource value for drinking water, recreation, fishing, and other uses.

Under the federal Clean Water Act (Section 303), the Missouri total maximum daily load (TMDL) program provides a framework for identifying and cleaning up impaired water bodies. Since nutrient runoff mainly comes from wastewater treatment plants, septic tank systems, animal waste, and fertilizers, the TMDL program requires significant cut of nutrient loads from point sources in order to meet the concentration limits (total phosphorus < 0.075 mg/L; total nitrogen < 1.5 mg/L) for some of the impaired water bodies (MoDNR, 2001). Correspondently, a mandatory discharge limit of 0.5 mg P/L is enforced to many wastewater treatment facilities in Missouri. However, these facilities were mostly designed for removal of organic matter and solids only. In an attempt to meet new permits, the US Environmental Protection Agency and local governments are investing multi-million dollars to upgrade or build new wastewater treatment facilities for biological nutrient removal (BNR). Unfortunately, many facilities that have already installed BNR processes are still experiencing intermittent and extended periods of higher levels of nutrient in their discharges than the mandatory permits.

The objective of this research is to develop a membrane aerated reactor system for efficient nitrogen and phosphorus removal from domestic wastewater through biotic and/or abiotic reactions. In this research, a gas-permeable membrane was applied as a carrier for aeration and nitrifying biofilm formation, and further, metallic iron materials will be introduced in anoxic basins to promote abiotic denitrification and chemical phosphorus precipitation.

Research Progress

A bench scale bioreactor with an operating volume of ~7L was built. The reactor consists of three compartments: an anaerobic fermentation basin followed by an anoxic basin, and further followed by an internal clarifier. In the anoxic basin, an aerated membrane module covered by nonwoven cloth was submerged. The reactor is operated under

## Progress Report for the United States Geological Survey, Department of Interior

constant hydraulic retention time (target HRT = 3 d), SRT (target  $SRT_{total} > 100$  d, and  $SRT_{anaerobic} > 50$  d). A nitrifying enrichment culture (collected in the lab previously) and activated sludge from the Columbia Wastewater Treatment Plant (Columbia, MO) was used as inocula. For laboratory process optimization only, pure oxygen was provided for aeration.

A gas permeable membrane support was constructed for immobilization of nitrifying bacteria and immersed in the bulk volume. The support consists of a gas-permeable membrane (Silastic® medical grade tubing, outer diameter = 2.0 mm and inner diameter = 1.4 mm, Dow Corning, active length = 10 m), the inner and outer sides of which were covered with a polypropylene nonwoven material (diameter = 10  $\mu$ m) to enhance the formation of nitrifying biofilm. Oxygen was supplied to the inside of the membrane tube at an airflow rate of ~2 ml/min.

The feed medium was designed to represent domestic wastewater, which contains the following (per liter of deionized water): 0.6 g sodium acetate, 0.1 g ammonium chloride, 0.28 g sodium phosphate, and the required macro/micro nutrients. The medium has an average chemical oxygen demand (COD) of approximately 470 mg/L,  $NH_4^+$ -N of 30 mg/L and TP of 6 mg/L. Nitrogen species, phosphorous and chemical oxygen demand (COD) were determined colorimetrically according to standard methods [APHA, 1998 #182].

COD and  $NH_4^+$ -N were monitored twice a week. In the membrane aerated biofilm reactor, the initial average influent COD was maintained for about 2 weeks at  $202 \pm 28$  mg/L and the average effluent COD was  $26 \pm 9$  mg/L, a 87% removal after the treatment. The influent COD was increased to  $340 \pm 39$  mg/L from day 28 onward and the average effluent COD was  $55 \pm 14$  mg/L, with an overall removal efficiency of 84% after the treatment.  $NH_4^+$ -N was removed in a similar pattern, with typical effluent  $NH_4^+$ -N concentrations less than 1 mg/L and an average removal rate of 93% throughout the membrane aerated reactor system. There was little nitrite (< 1 mg/L) accumulated during continuous operation. The average effluent  $NO_2^-$ -N concentration was 0.3 mg/L. Nitrate removal was considerably improved under controlled aeration. The effluent total N concentrations after treatment were 2.1 mg/L indicating overall efficient nutrient removal in membrane aerated systems at the beginning of the reactor operation. Further work is needed to evaluate nutrient removal efficiency as the sludge continues to accumulate in the reactor.

The average influent and effluent phosphorous concentrations, however, were 6 and 5.1 mg/L respectively, indicating low biological phosphorous removal with the existing treatment system. The potential improvement of phosphorous removal will be evaluated by adding steel wool to the reactor to facilitate phosphate precipitation.

## **Progress Report for the United States Geological Survey, Department of Interior**

### Students Directly Supported

Zhihua Liang (M.S. from North Carolina State University), Ph.D. student in environmental engineering, anticipated completion date: Summer 2011.

The Ph.D. student is responsible for daily operation of bioreactors, respirometric study, chemical and nutrient analysis during the funding period. Mr. Liang continues to compile, collates and synthesize data for reports, and professional publications.

In addition, an undergraduate minority student, Ryan Womack from Morehouse College, Atlanta, GA, will work with Mr. Liang in the summer 2008 to foster his interest in scientific discoveries through hands-on experience.

### Publications

Liang, Z. H., Nguyen, H. Hu, Z. Q. **2008**. "Nutrient removal in on-site wastewater treatment systems using membrane-aerated bioreactor techniques." Proceedings at the Missouri MWEA/AWWA 2008 Joint Annual Meeting, March 31 - April 2, 2008, Tan-Tar-A Resort, Osage Beach, Missouri

### Supplemental Grants Obtained

US EPA. "Enhanced nutrient removal from on-site wastewater treatment systems," Hu, ZQ, Thompson, AL and Kathleen, MT, \$10,000

# Relation Between Spatial Variation of Bed–Shear Stress Distribution and the Statistical Characterization of Bed Material in the Missouri River

## Basic Information

<b>Title:</b>	Relation Between Spatial Variation of Bed–Shear Stress Distribution and the Statistical Characterization of Bed Material in the Missouri River
<b>Project Number:</b>	2007MO71B
<b>Start Date:</b>	3/1/2007
<b>End Date:</b>	2/28/2008
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	9
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	Sediments, Methods, Hydrology
<b>Descriptors:</b>	None
<b>Principal Investigators:</b>	Jerry Richardson, Richard Geekie

## Publication

Progress Report  
USGS Grant # 06HQGR0095  
WRI's award ID # Richardson 0018302/00019915  
USGS Ref # 2007MO71B  
Year 1  
Start Date 2-29-2007  
End date 2-28-2008 (\*)

**Note:** *Although the official, original start date for this grant was February 2007, the funding for the grant was deferred for 6 months. Because of this, work on this grant was not started until the beginning of the 2007-2008 academic year (August 2007). As such the progress reported for Year 1 represents effort for only 7 months.*

**Accomplishments:**

1. The comprehensive review of literature has been completed. Additional literature is being added as the project progresses.
2. Computer software, MIDAS, ARC-View, Soil-Vision Lite were obtained.
3. The computer program, MIDAS, developed by Penn State University was obtained and modified to facilitate direct entry of bed shear stress into the operation of the program. This study will not use flow variables are channel geometry because the scale of the investigation is only 12 to 36 meters in length and the width of the sections is no more than two meters.
4. Preliminary runs of the MIDAS program have been developed to help formulate the various combinations of independent variables to establish a preliminary understanding of the dependency of the bed-material composition to the independent variables.
5. Chapter 1 of Mr. Geekie's Dissertation (introduction) has been finished and chapter 2, (Review of the literature and the theory of the sediment transport at the dune level) is approximately 2/3 completed.
6. Some work on chapter 3, an overview of the lower Missouri River and its characterization as a navigation channel has been done.
7. Preliminary data analysis has been conducted with the USGS bed samples collected from the Missouri River between 1991 and 2001. Statistics such as mean, median, standard deviation, skew and kurtosis have been calculated for three river gages and plotted in different combinations. Additionally, the median grain size has been plotted for the lower 500 miles of the Missouri River. This data is the result of the Corps of Engineers data sampling program which is conducted every four to six years. These two data sets (USGS and Corps) provide clues as to what the relationship between sediment supply from upstream and local shear stress distributions have with the changing local bed-material composition.

**Anticipated accomplishments Year 2:**

Significant progress is anticipated during Year Two of this project in that this will be the first full year of the project. By the end of year 2 (February, 2009), the project should be approximately 75 % complete. Specifically:

1. Data analysis will have been conducted with the USGS bed samples collected from the Missouri River between 1991 and 2001. Statistics such as mean, median, standard deviation, skew and kurtosis will have been completed and analyzed.
2. Similar analysis of the median grain size has been plotted for the lower 500 miles of the Missouri River will be complete. This data is the result of the Corps of Engineers data sampling program which is conducted every four to six years. These two data sets (USGS and Corps) provide clues as to what the relationship between sediment supply from upstream and local shear stress distributions have with the changing local bed-material composition.
3. The Draft of Mr. Geekie's dissertation will be nearly complete. This dissertation will document this investigation as to how bed-material composition changes with changes in the upstream sediment supply and local shear stress distributions. This study is different from others in that the scale of the study is not much longer than the length of a dune

**No Cost Extension:**

Due to the delayed start for this project, it is anticipated that a request for a no-cost extension will be required to complete the project. This extension will provide the required physical amount of time (two full summers) that we planned on having to conduct this study. During this extension time we plan on finalizing and defending Mr. Geekie's dissertation, and writing/submitting papers for publication.

**Publications:**

No publications during the first ½ year.

**Students Supported:**

Mr. Richard Geekie, Ph.D. Candidate

Respectfully submitted

J. R. Richardson PI

July 9, 2008

**Problems Encountered:**

Other than the deferred start, no problems have been encountered.

# Information Transfer Program Introduction

# Tech Transfer – USGS Water Resources Research Center

## Basic Information

<b>Title:</b>	Tech Transfer – USGS Water Resources Research Center
<b>Project Number:</b>	2007MO72B
<b>Start Date:</b>	3/1/2007
<b>End Date:</b>	2/28/2008
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	9th
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	Management and Planning, None, None
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Thomas E. Clevenger, Thomas E. Clevenger

## Publication

The Missouri Water Resources Research Center's objectives are: 1) to establish active research programs to aid in understanding and solving Missouri's and the Nation's water problems, 2) to provide education opportunities in research for students with an interest in water resources and related fields, and 3) to be actively dedicated to the dissemination of information through all aspects of the media.

The technology assistance program goal is to meet objective 3, dissemination of information through all aspects of the media.

During FY2007 the Center maintained an active information transfer program that included:

- Water Board Training and Community Outreach in cooperation with Northwest Missouri State University and MU Extension.  
-Training course for drinking water. The Water Partnership Team members elected officials, agency representatives and service providers. Instruction was designed to develop core competencies required for effective drinking water system management and planning.
- Assistance in the organization of statewide conferences
- Coordination of local seminar program
- Interaction with state and federal water agencies
- Cooperation with University extension personnel (they are represented on advisory committee)
- Director serves on various national and local water related boards, organizations and committees
- Continued cooperation with district USGS office (representative on advisory committee)
- Maintenance and expansion of comprehensive web site
- Making available of Center's publications
- Continue to respond to public requests and questions for information

# Student Support

<b>Student Support</b>					
<b>Category</b>	<b>Section 104 Base Grant</b>	<b>Section 104 NCGP Award</b>	<b>NIWR-USGS Internship</b>	<b>Supplemental Awards</b>	<b>Total</b>
<b>Undergraduate</b>	3	0	0	0	3
<b>Masters</b>	0	0	0	0	0
<b>Ph.D.</b>	2	0	0	0	2
<b>Post-Doc.</b>	0	0	0	0	0
<b>Total</b>	5	0	0	0	5

## **Notable Awards and Achievements**

Supplemental Grants Obtained US EPA. “Enhanced nutrient removal from on-site wastewater treatment systems,” Hu, ZQ, Thompson, AL and Kathleen, MT, \$10,000

## Publications from Prior Years

1. 2006MO61B ("EEM Fluorescence Spectroscopy Fingerprints and Monitoring of NDMA and TTHM Formation Potentials") – Articles in Refereed Scientific Journals – Hua, B., F. Dolan, C. McGhee, T. Clevenger, B. Deng, 2007, Water–source characterization and classification with fluorescence EEM spectroscopy: PARAFAC analysis, International Journal of Environmental Analytical Chemistry, 87(2), 135–147.