Missouri Water Resources Research Center
Annual Technical Report
FY 2015

Introduction

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. And as part of the food, water, and energy nexus, water contributes in a major way to the urban and rural communities in the state.

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. Other concerns include the odor and taste issues when Missouri River water is used as source water for water supplies. With the large agricultural activity in the state, non-point source pollution is also 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 water 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, nutrient management, water treatment and disinfection byproduct controls, wastewater treatment and reuse coupled with algal bioenergy production, acid precipitation, anthropogenic effects on aquatic ecosystems and wetlands.

Water Quantity

Missouri has a history of variable rainfalls. Because of the several drought years and major floods, water quantity has become a major topic of concern. The drought in 2012 was particularly notable with all counties in the State of Missouri being declared drought disaster areas with diminished agricultural and economic activities. Research is needed to better understand droughts and flood conditions. Many reservoirs have been constructed in Missouri to address water shortage issues; research is needed to understand how the agricultural activities affect water quality and how to best manage reservoirs and regional land use as a system. Also, a critical aspect is that research is needed on water treatment/reuse coupled with nutrient management.

Water Policy

Policies and programs need to be formulated that will ensure continued availability of water for designated uses, 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. Best approaches for managing non-point source pollution need to be derived. 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.

Research Program Introduction

WATER PROBLEMS AND ISSUES OF MISSOURI

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Recent research activities include the following:

Stormwater Program

Federal regulations require MU, City of Columbia and Boone County to protect the quality of surface water from stormwater runoff. The Water Center has several projects to evaluate best management practices (BMPs) that will detain and filter the runoff. One project involves a diverse group from across the University of Missouri campus to understand the best management practices for stormwater at the University of Missouri. The student team is laying groundwork to evaluate existing projects in preparation of data collection that will be used to inform future decisions. Allen Thompson, associate professor of biological engineering serves as principal investigator for the project. In addition, Bob Reed research associate professor, Enos Inniss, assistant professor and Robert Broz, extension assistant professor with agricultural engineering, round out the mentoring team.

Renewable Energy

Ground source heat pump technology is being studied with application to the agriculture sector. The constant temperature of the ground represents an incredible source of environmentally friendly, sustainable energy to heat and cool the buildings. Dr. Shawn Xu, Research Associate Professor with the Water Center, is installing ground source systems on turkey farms in Central Missouri. The energy system is part of a Department of Energy grant ($5,000,000) that Dr. Xu received to introduce the technology into agriculture applications.

Another project supported by the USDA under Drs. Robert Reed and Shawn Xu is focused on energy efficiency and control of ammonia in turkey farms.

Drinking Water

The Water Resources Research Center is working with several Missouri communities to manage disinfection byproducts (DBPs) that are produced during the disinfection of drinking water. DBPs are regulated compounds that can could cause cancer. Led by Assistant Professor Enos Inniss and Research Associate Professor Robert Reed, the MOWRRC research teams analyze the chemical makeup of water within each community's treatment plant, water storage towers and distribution system throughout the year. The researchers will then test how certain chemicals affect the water samples in order to identify options for complying with EPA guidelines. Funding has been available from EPA, Mo DNR, and various Missouri communities. Another project on the control of DBPs is to develop advanced ultra-filtration membranes to remove natural organic matters (NOMs), supported partially by the Water Center with Dr. Hu being the PI. A detailed technical report is attached. NOMs are precursors for DBP formation, and while nanofiltration and reverse osmosis are effective at removing NOMs, the cost is relatively high. Ultrafiltration could be implemented at a much lower cross-membrane pressure and thus could be a cost-effective way for NOM removal and control of DBPs.

Removal of NOMs by Advanced Thin Film Composite Membranes for the Control of Disinfection Byproducts

Basic Information

Title:	Removal of NOMs by Advanced Thin Film Composite Membranes for the Control of Disinfection Byproducts
Project Number:	2015MO147B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	4
Research Category:	Water Quality
Focus Category:	Treatment, Water Quality, Nutrients
Descriptors:	None
Principal Investigators:	Zhiqiang Hu

Publications

1. Yin, J.; B. Deng, 2015, "Polymer-matrix nanocomposite membranes for water treatment", Journal of Membrane Science, 479, pp 256-275.
2. Ding, C.; J. Yin; and B. Deng, 2014, Effects of Polysulfone (PSF) Support Layer on the Performance of Thin-Film Composite (TFC), Journal of Chemical and Process Engineering, Vol 1102, Pages 1-8.
3. Yang, Z.; Yin, J.; and Deng, B. (2016) “Enhancing water flux of thin-film nanocomposite (TFN) membrane by incorporation of bimodal silica nanoparticles”, AIMS Environmental Science, 3(2): 185-198.
4. Hu, W.; Yin, J.; Deng, B.; Hu, Z. (2015) “Application of nano TiO2 modified hollow fiber membranes in algal membrane bioreactors for high-density algae cultivation and wastewater polishing”, Bioresource Technology, 193: 135–141.
5. Wang, X. 2014, Ultrafiltration of surface water by poly(vinylidene fluoride) (PVDF)/TIO2 mixed matrix hollow fiber membranes (HFMs) with advanced antifouling properties under visible light irradiation, M.S. Thesis, Department of Chemical Engineering, University of Missouri, Columbia, MO, 58. Engineering, University of Missouri, Columbia, MO.

Removal of NOMs by Advanced Thin Film Composite Membranes for the Control of Disinfection Byproducts

Progress report:

The overall goal of this research is to develop high performance mixed matrix nano composite membranes (MMM) that could be used to effectively remove NOMs from the source water and thus decrease or eliminate the formation of DBPs during water chlorination. It has been well established that NOMs serve as precursors for the formation of DBPs so the removal of NOMs will result in the reduction of DBP formation potentials under otherwise the identical conditions. In the project, our research has focused on the development of advanced nanocomposite membranes and assessing their performance for water filtration, membrane antifouling characteristics, and capability for the removal of NOMs.

In the first year, the research focused primarily on evaluating the impact of nitrogen doped TiO_2 (N-TiO_2), a hydrophilic and visible light-active photocatalyst, on the poly(vinylidene fluoride) (PVDF) matrix hollow fiber membranes (HFMs). The membranes were characterized by scanning electron microscopy (SEM), contact angle measurement and UV-Vis absorbance. The membrane performances for treating surface water were evaluated based on the water flux, humic acid (HA) rejection and total organic carbon (TOC) rejection in surface water. Different water samples were collected from Eagle Bluffs, Missouri River and McBaine Water Treatment Plant in Columbia, MO. The results showed the pure water flux of PVDF-NTiO_2 membranes, which was about 28.5±0.3 L/m2 h at the transmembrane pressure (TMP) of 8 psi under visible light, was slightly higher than the flux of pure PVDF membranes around 25.6±0.4 L/m2 h. The contact angle of the PVDF-NTiO_2 membranes (about 43°) was smaller than the pure membranes' contact angle (about 55°), suggesting that the membrane hydrophilicity was significantly improved by incorporating TiO_2 nanoparticles into the PVDF HFMs. The as-prepared PVDF-NTiO_2 mixed matrix membranes removed over 40% of humic acid and 20% of TOC in the water samples collected from the Eagle Bluffs and Missouri River and rejected 20% of HA and TOC in water from the McBaine Water Treatment Plant, which were comparable to pure PVDF membranes. The mixed matrix membrane with N-TiO_2, however, showed much better resistance to membrane fouling. The study suggests that the PVDF-NTiO_2 membranes with enhanced water flux and anti-fouling characteristics could treat water more efficiently for control of natural organic matter.

In the second year, we continued the research with an ultrafiltration membrane that contained oxidized multi-walled carbon nanotubes (OMWNTs) dispersed in polysulfone (PSU) polymer. The fluorescence excitation/emission matrix (EEM) spectra of water samples indicated that the dominant dissolved organic matters (NOMs) in the natural water samples were humic acid in nature. The nanocomposite membranes showed improved water fluxes (30% ~ 50%) and fouling resistance during the water filtration process, while maintaining a solute rejection rate comparable to the conventional PSU membranes. The flux increase was attributed to the increased surface hydrophilicity and porosity of membrane after embedding hydrophilic OMWNTs. The H20-0.5 membrane has UV254 removal rates around 48%, 52%, and 38% for water samples from Eagle Bluffs, Missouri River, and Water Treatment Plant, respectively. Meanwhile, for the same membrane, the THMs removal rates are around 70%, 40%, and 27%, respectively. Overall, the study demonstrated that OMWNTs/PSU ultrafiltration membranes could be applied to remove a portion of NOMs in water samples at a relatively low cross membrane

pressure, and such treatment can significantly reduce the THMs formation potential so the regulatory standards for THMs could be met following the water disinfection process using chlorine.

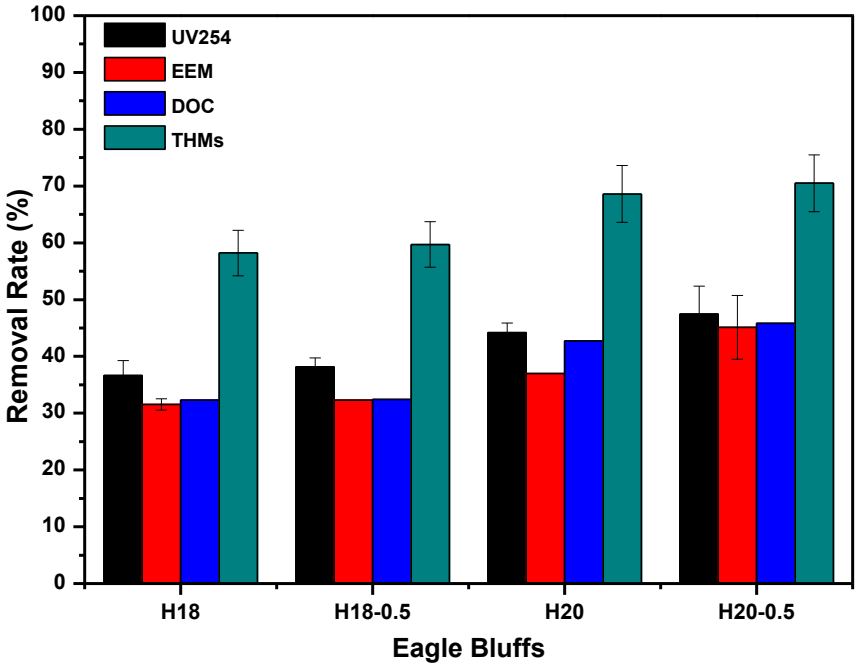

Figure 1. Treatment performance of membranes containing 18% or 20% PSU for the filtration of water samples from Eagle Bluffs. The TMP is 10 psi.

Student support

The project provided support for research by two students:

Weiming Hu, PhD student

Zhengyang Wang, PhD student

Publications

1. Yin, J.; B. Deng, 2015, "Polymer-matrix nanocomposite membranes for water treatment", *Journal of Membrane Science*, 479, pp 256-275.
2. Ding, C.; J. Yin; and B. Deng, 2014, Effects of Polysulfone (PSF) Support Layer on the Performance of Thin-Film Composite (TFC), *Journal of Chemical and Process Engineering*, Vol 1102, Pages 1-8.
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4. Hu, W.; Yin, J.; Deng, B.; Hu, Z. (2015) “Application of nano TiO2 modified hollow fiber membranes in algal membrane bioreactors for high-density algae cultivation and wastewater polishing”, *Bioresource Technology*, 193: 135–141.
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Information Transfer Program Introduction

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 goal of the Information Transfer Program is to meet objective 3, dissemination of information through all aspects of the media.

The Center maintained an active information transfer program that included: 1) coordination of the University of Missouri seminar program, 2) publication of Water Center newsletter, 3) interaction with state and federal water agencies, 4) Director served on various national and local water related boards, organizations and committees, 5) continued cooperation with district USGS office (representative on advisory committee), 6) maintenance and expansion of comprehensive web site, 7) making available of Center's publications, 8) responding to public requests and questions, 9) meeting with advisory committee to improve information transfer activities.

Technology Transfer

Basic Information

Title:	Technology Transfer
Project Number:	2015MO146B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	4
Research Category:	Not Applicable
Focus Category:	Water Quality, Water Quantity, Water Supply
Descriptors:	None
Principal Investigators:	Baolin Deng

Publications

There are no publications.

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Coordination of Seminar Program

The Water Resources Research Center hosted a joint University of Missouri-Columbia seminar series with Civil & Environmental Engineering & Chemical Engineering throughout the year. In addition, other special seminars included speakers from out of state and internationally to speak on a variety of topics:

1) Dr. Bruce Rittmann, Regents' Professor of Environmental Engineering and Director of the Swette Center for Environmental Biotechnology in the Biodesign Institute at Arizona State University, Making CO2 a Resource, Not a Liability.

2) Dr. Bruce Rittmann, Regents' Professor of Environmental Engineering and Director of the Swette Center for Environmental Biotechnology in the Biodesign Institute at Arizona State University, Prying Open the Black Box.

3) Dr. Gang Wu, University of Buffalo, Large-size Graphene Tube Catalysts for Sustainable Electrochemical Energy Storage and Conversion.

4) Dr. Krista Walton, Georgia Institute of Technology, Porous Metal-Organic Frameworks for Adsorption Applications.

5) Dr. Mark Wiesner, Duke University, Surface Affinity: Applications of a Functional Assay for Quantifying Nanoparticle Transport, Aggregation, Transformation and Bio-Uptake in Complex Systems.

6) Dr. Sheng Dai, University of Tennessee, Tailoring Mesoporous Carbons and Related Materials for Energy Applications.

7) Dr. Kelly O. Sullivan, Pacific Northwest National Laboratory, Pacific Northwest National Laboratory: Scientific Leadership that Transforms the World.

8) Mr. Ronald Wood, Founder of Wood Capital, LLC and Chief Executive Officer of Tiger Energy Solutions, LLC. Mr. Wood was also President and CEO of Black & Veatch. An Integrated Water, Food, Electricity & Sanitation System.

9) Professor Lina Zhang, Wuhan University, Construction of Functional Materials from Cellulose and Chitin in NaOH/Urea Aqueous Solutions with Cooling.

10) Dr. Jun Yin, University of Missouri, Designing Nanocomposite Membranes for Efficient Water Treatment and Reuse.

11) Dr. Julian Fairey, University of Arkansas, Occurrence of Regulated and Emerging Disinfection By-Products in Drinking Water.

Publication of the Water Center Newsletter

The Water Center newsletter is a yearly publication. The purpose of the Center's newsletter is to inform the scientific community as well as the public, on the activities of the Center, i.e., new research projects funded, and upcoming conferences. The Center's primary focus is on its own information transfer activities and the general scope of the projects that were funded. Highlights of the 2014 Newsletter can be seen on the Missouri Water Resources Research Center website at http://engineering.missouri.edu/water/.

Conferences

Mid-American and Environmental Engineering Regional Conference

The Missouri Water Resources Research Center hosted the Chancellor's Distinguished Visitor Lecturer, Dr. Bruce Rittmann, Regents' Professor of Environmental Engineering and Director of the Swette Center for Environmental Biotechnology in the Biodesign Institute at Arizona State University. Dr. Rittman, gave a presentation "Making CO2 a Resource, Not a Liability" at 4:30 p.m. Friday, October 23, 2015, in Lafferre Hall Ketcham Auditorium. This event was free and open to the public.

In addition, the Water Resources Research Center hosted the Mid-American and Environmental Engineering Regional Conference (MAEEC) on October 24, 2015. Dr. Rittmann also gave a presentation on, "Prying Open the Black Box". The MAEEC Conference, brings together a

network of universities to increase communication and collaboration between the schools and also gives a chance for graduate students from all participating universities a chance to hone their skills through oral and poster presentations. It was very impressive to have someone of his caliber to talk to our graduate students and give this visibility to MU.

Dr. Rittmann met with many faculty, within the College, the University, and the schools involved in the Conference during his stay here, and shared with faculty how he was able to build a successful program and what it takes to maintain such a program.

The opportunities provided in this conference further enriched interactions between MU, and the other participating universities including Missouri S&T, Southern Illinois University Carbondale, Southern Illinois University Edwardsville, and Washington University in St. Louis and future collaboration on the issues being faced in the food/water/energy areas. There were discussions with the faculty on establishing some cooperative projects.

The main purpose of Professor Bruce Rittmann's visit was to mentor MU's faculty and students by delivering seminars and developing potential collaborative research. We believe this was accomplished. In addition, the states of Missouri and Arkansas are preparing a joint EPSCoR Track II proposal to NSF. He has agreed to serve on the Advisory Board if this proposal is funded.

Notable Awards and Achievements

The Water Center was awarded funds to host the Chancellor's Distinguished Visitors Program Lecture.

The Missouri Water Resources Research Center (MOWRRC) received an award of $3,850 from the Sustainable Energy Focus Area of the Mizzou Advantages Program to help sponsor the annual Mid-American Environmental Engineering (MAEEC) Conference which was held in Columbia, Missouri on October 23-24, 2015.

The MAEEC Conference, brought together a network of universities including MU, Missouri S&T, Southern Illinois University Carbondale, Southern Illinois University-Edwardsville, and Washington University in St. Louis, to increase communication between the schools and also provide opportunities for graduate students to hone their presentation skills.

This conference provided the Water Center the platform to talk about current and future priorities for Missouri's environment.

Important areas of concern in Missouri include climate variability, soil and water health, education/extension/economic development, water policy, information management/GIS, and infrastructure/water supply. Energy will be an integral part of each of these areas, but will be especially critical in climate variability and water policy. New laws to protect water may effect rising energy costs and availability.

USGS Summer Intern Program

None.

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

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Baolin Deng, Director of the MOWWRC, was invited to serve as a member of the U.S. Environmental Protection Agency Science Advisory Board's Drinking Water Committee for a term ending September 30, 2018.

Publications from Prior Years

1. 2011MO122B ("Urban Water Quality: Value of Green Roof Technology") - Conference Proceedings - Gibler, M. R., 2015, "Comprehensive Benefits of Green Roofs", in EWRI-ASCE World Environmental & Water Resources Congress Austin, Texas, May 17-21, 2015, pp. 2244-2251,
2. 2011MO122B ("Urban Water Quality: Value of Green Roof Technology") - Dissertations - Gibler, M. R., (2015) Comprehensive Benefits of Green Roofs, MS Thesis, Missouri University of Science and Technology, Rolla, MO.
3. 2011MO122B ("Urban Water Quality: Value of Green Roof Technology") - Articles in Refereed Scientific Journals - Gibler, M. R., M.A., Limmer, J.G. Burken, (2016 Submission) " Linking Water And Energy Benefits Of Green Roofs", to Building and Environment
4. 2015MO147B ("Removal of NOMs by Advanced Thin Film Composite Membranes for the Control of Disinfection Byproducts") - Articles in Refereed Scientific Journals - Yin, J.; B. Deng, 2015, "Polymer-matrix nanocomposite membranes for water treatment", Journal of Membrane Science, 479, pp 256-275.
5. 2015MO147B ("Removal of NOMs by Advanced Thin Film Composite Membranes for the Control of Disinfection Byproducts") - Articles in Refereed Scientific Journals - Ding, C.; J. Yin; and B. Deng, 2014, Effects of Polysulfone (PSF) Support Layer on the Performance of Thin-Film Composite (TFC), Journal of Chemical and Process Engineering, Vol 1102, Pages 1-8.
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