July 2011

North Dakota Water Resources Research Institute
North Dakota State University Fargo, ND
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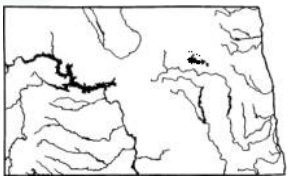


Newsletter

The National Institutes for Water Resources

http://www.ndsu.edu/wrri

From the Director

North Dakota is experiencing record floods again this year! Just when we thought the flooding along Red river has receded, the Missouri river is raging all the way from Montana to Louisiana. It appears all of the reservoirs along Missouri river are full so there is no place to put water in. Surges of water from upstream dam releases raise concern of the safety of levees downstream. Holding back would have meant threatening the integrity of dams. As the Army Corps of Engineers plan more water releases along the Missouri River concerns about levees grow. Water levels are not expected to decrease until mid-August. It is not so much the amount of water that has people along the nation's longest waterway on edge; it is how long all that water will stick around.

In North Dakota, it was first along the Red river and then along Missouri, Little Missouri, and Souris rivers. Minot and Bismarck cities have experienced unprecedented flooding. About 11,000 residents in Minot were evacuated and later allowed back into their homes only to be subjected to compulsory long-term evacuation again on June 22. Souris River overtopped the dike system of Minot city submerging 4100 homes in water. This year's flooding has taken a tremendous toll on the infrastructure of the western parts of the state, already stressed by the oil development. Devils Lake flooding is not getting better either.

Our hearts and prayers go out to everyone affected by the unprecedented flooding.

Again this year, North Dakota State Water Commission extended its support of 15% of the USGS annual base grant to the Fellowship program of the Institute. As in the previous years, the State Advisory Committee provided valuable help in setting Institute's research priorities and reviewing Fellowship applications.

The Institute fared well in its 5-year evaluation for the period 2003-2007. The reviewers commended the Institute for its fellowship program and the information dissemination program through its website and newsletter. Another aspect that received praise is the development of scientific water expertise with the students and junior faculty.

In this issue of newsletter, 2011 NDWRRI Fellowship recipients are introduced and last year's Fellowship research projects are highlighted. Four WRRI-affiliate faculty are featured and research by some Institute faculty research groups are also presented. We encourage you to visit the Institute website, www.ndsu.edu/wrri or contact the respective Fellows, advisors, or principal investigators for details of research projects.

Institute faculty and fellows presented the results of their research in several conferences and symposia as in the past years. Their recent publications and presentations can be found in this issue. Technical reports of several Fellowship projects are available on the Institute web site. Several WRRI Fellows graduated and moved on to accept responsible positions in various water-related areas of employment.

G. Padmanabhan, Director
North Dakota Water Resources Research Institute
Phone: 701 231 7043 e-mail: G.Padmanabhan@ndsu.edu

Inside this issue:

2010 — 2011 Fellows and their projects

Fellows, areas of study, their advisers and fellowship research projects are:

Adam Guy, soil science, Tom DeSutter, "The Impact of Rural and Urban Flooding on Water and Soil Quality in the Red River Valley of the North"

Andrea Hanson, biological Sciences, Mark Sheridan, "Uptake and effects of environmental estrogens on growth of fish"

Anusha Balngoda, civil engineering, Wei Lin, "Studies of Seasonal Succession of Cyanobacteria and Green algea Heinrich-Martin Impoundemtn, North Dakota"

Brianna Schneck, biological sciences, John McEvoy and Mark Clark, "Source Tracking of Cryptosporidium in Rural Watersheds"

Dhritikshama Roy, civil engineering, Achintya Bezbaruah and Eakalak Khan, "Plant-based Biopolymers for Entrapping Metal Nanoparticles for Arsenic Removal: Biodegradation and Treatability Studies"

Dimuthu Wijeyaratne, environmental and conservation sciences, Marinus Otte, "Chemical Fingerprinting of Sediments and Water of the Souris River for Identification of Diffuse Pollution Sources"

Halis Simsek, civil engineering, Eakalak Khan, "Fate of Biodegradable Dissolved Organic Nitrogen in Fargo Waste Water"

Harjyoti Kalita, materials and nanotechnology, Achintya Bezbaruah and Bret Chisholm, "Iron Imprinted Polymer for Removal and Monitoring of Arsenic"

Ishara Rijal, agriucultural and biosystems engineering, Xinhua Jia, "Reference Evapotranspiration and Actual Evapotranspiration Measurements in North Dakota"

Qigang Chang, environmental and conservation sciences, Wei Lin, "Development of GAC-NZVI Adsorbent for Arsenic Removal"

Upcoming Events

National Water Resources Association's Western Water Seminar, Cheyenne Mountain Resort, Colarado Springs, CO, July 25-27, 2011. http://www.nwra.org/media/uploads/2011_WWS_Registration_Form.pdf

AWRA 47th Annual Water Resources Conference, Albuquerque, NM, November 7-10, 2011 http://www.awra.org/meetings/ABQ2011/

National Rural Water Association's Conference. Ventana Canyon Resort, Tuczon, Arizona, November 16-18, 2011. http://www.nwra.org/events/2011/11/annual-conference/

North Dakota Water Quality Monitoring Conference, Bismarck, ND, February 27-29, 2012.

Sustainable Water Management Conference, Portland, Oregon, March 8-12, 2012. http://www.awwa.org/Conferences/SpecConf.cfm?ItemNumber=56511&navItemNumber=56514

National Water Quality Monitoring Council's (NWQMC) 8th National Monitoring Conference "Water: One Resource – Shared Effort – Common Future," Portland, Oregon, April 30 - May 4, 2012. http://acwi.gov/monitoring/conference/2012/

ASCE/EWRI World Environmental and Water Resources Congress, Albuquerque, NM, May 20-24, 2012. http://content.asce.org/conferences/ewri2012/

American Water Works Association's 131st Annual Conference & Exposition, June 10 -14, 2012, in Dallas, TX. http://www.awwa.org/ACE12/index.cfm?ItemNumber=56774&navItemNumber=56940

The Institute Awarded Fifteen Graduate Fellowships for the Year 2011-2012

Fellow: Andrea Hanson

Title: Uptake and effects of environmental estrogens on growth of fish

Advisor: Mark Sheridan, Department of Biological Sciences, NDSU

Fellow: Dhritikshama Roy

Title: Plant-based Biopolymers for Entrapping Metal Nanoparticles for Arsenic Removal: Biodegradation and Treatability Studies

Advisor: Achintya Bezbaruah, Department of Civil Engineering, NDSU

Fellow: Anusha Balangoda

Title: Studies of Seasonal Succession of Cyanobacteria and Green algae Heinrich-Martin Impoundment, North Dakota

Advisor: Wei Lin, Department of Civil Engineering, NDSU

Fellow: Hasin Shahad Munna

Title: Flood Risk Assessments of Various Scenarios for Devils Lake under GCM Downscaling Simulations

Advisor: Howe Lim, Department of Civil Engineering, UND

Fellow: Brianna Schneck

Title: Source tracking of Cryptosporidium in rural watersheds

Advisors: John McEvoy, Microbiology, and Mark Clark, Department of Biological Sciences, NDSU

Fellow: Justin Fisher

Title: Integrating life stage habitat into landscape genetics model for the conservation of declining amphibian species

Advisor: Craig Stockwell, Department Biological Sciences, NDSU

Fellow: Christopher Capacchi

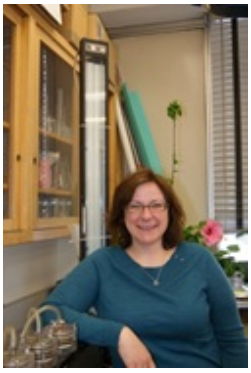
Title: Arsenic Contaminated Groundwater Remediation by Entrapped Nanoscale Zero-Valent Iron

Advisor: Achintya Bezbaruah, Department Civil Engineering, NDSU

Fellow: Kate Overmoe-Kenninger

Title: Assessment of Water Quality in Devils Lake using Satellite Imagery

Advisor: Xiaodong Zhang, Department Earth Systems Science, UND



Fellow: Katrin Chamber

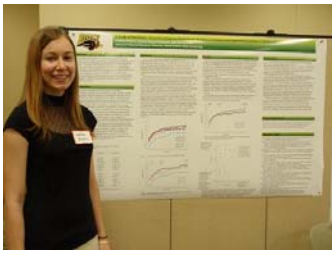
Title: Bioavailability of Dissolved and Colloidal Organic Carbon Bound Estrogen

Advisor: Frank Casey, Department Soil Science, NDSU

Fellow: Kyle Hafliger

Title: Techniques of Assessing Changes in River Flooding Patterns in the Upper Midwest

Advisor: Howe Lim, Department of Civil Engineering, UND



Fellow: Lindsey Malum

Title: Ecosystem Services and Wetland Condition Assessment in Prairie Pothole Region

Advisors: Edward Dekeyser and Jack Norland, School of Natural Resources Sciences, NDSU

Fellow: Mohammed Mizanur Rahman

Title: Hydologic Adaptation of SWAT Model for Snow Dominated and High Groundwater Table Conditioned Watersheds and Scenario Analysis of Impacts of Tile Drainage on Stream Flow

Advisor: Zhulu Lin, Department of Agricultural and Biosystems Engineering, NDSU

Fellow: Sharanya Shanbhogue

Title: Co-entrapment of Iron Nanoparticles and Tricholoroethylene Degrading Bacteria in Alginate Biopolymer

Advisors: Achintya Bezbaruah and Eakalak Khan, Department of Civil Engineering, NDSU

Fellow: Tanush Wadhawan

Title: Role of Agricultural Drainage on Transport of Cryptosporidium Oosysts in North Dakota

Advisors: Eakalak Khan, Civil Engineering, and John McEvoy, Department of Microbiology, NDSU

Fellow: Veselina Valkov

Title: Temporal-spatial Distribution of Phytoplankton and Diversity in Relation to Lake Physical and Chemical Condition

Advisor: Wei Lin, Department of Civil Engineering, NDSU

2010 — 2011 NDWRRI Fellowship Research Highlights

Adam Guy

Adam investigated the quality of sediment in water and after deposition on land before, during, and after the floods. His findings indicate the quality of the sediment remaining after flooding waters recede would not be considered harmful. Thus, human activity, including recreation and gardening, would be safe. In addition, the deposition of high concentrations of carbon, phosphorus, and nitrogen by flooding waters and sediments should lead to a decreased demand for synthetic fertilizers in these flooded areas, which would reduce any negative water quality impacts from fertilizers to the Red River.

Andrea Hanson

The aim of this project is to advance our understanding of the fate of environmental estrogens (EE) in aquatic ecosystems by measuring their uptake and metabolism and evaluating the impact as assessed by organismal growth. Results support the hypothesis that EE reduce growth in fish by modulating the Growth Harmone- Insulin-like Growth Factor-1 (GH-IGF-1) system in terms of GH sensitivity, IGF production, and IGF sensitivity in a tissue-specific manner at the molecular level and in terms of overall organismal growth. Currently, experiments are being conducted examining the in vitro response in muscle tissue of rainbow trout. These current data, in addition to the muscle data, will allow us to fully characterize the time course and efficacy of EE on IGF-1 binding characteristics and on the growth-promoting actions of IGF-1 in target tissues.

Anusha Balangoda

The purpose of this study is to identify population variation of cyanobacteria and green algae in relation to their growth requirements. It is suggested that the Heinrich Martin Impoundment (HMI) is an N-limiting impoundment. Seasonal variation of phytoplankton community structure was observed in the HMI. Total phytoplankton cell densities were varied along the depths and spatially. Eight phytoplankton divisions were counted and identified up to genus level. Among them; Bacillariophyta, Crptophyta, and Dinophyta were important of the phytoplankton community during much of the sampling period and contributed greatly to the total phytoplankton cell density at all depths. In addition, Chlorophyta and Cyanophyta were also observed at all depths, contributed relatively little to total phytoplankton cell density. The factors that affect growth of phytoplankton, especially the seasonal growth and succession of cyanobacteria are in progress.

Brianna Schneck

The main objective of this research is to determine the factors influencing the contributions of cattle and wildlife to *Cryptosporidium* in rivers, especially in the Red River Valley. *Cryptosporidium* are ubiquitous pathogenic parasites that can reside in water sources and may pose a threat to public health. We sampled the Red River and its tributaries during major flooding events in 2009 and 2010 for *Cryptosporidium*. Spring flooding results in the movement of *Cryptosporidium* from the fields of North Dakota, South Dakota and Minnesota to the Red River. Livestock contributed significantly to *Cryptosporidium* contamination in the Red River during major spring floods. Cattle were the primary source of surface water contamination. We estimated the flow of oocysts during peak flooding in 2010 at 728,000 per second, based on our oocyst counts and a river flow of 560,000L per second. This is significant considering that only less than 100 oocysts are needed to infect a host.

Dhritikshama Roy

This project studied biodegradability of polymers used for coating NZVI, and will experiment with a few new biopolymers and use them for contaminant (e.g., arsenic) remediation. Biodegradation batch studies with polydimethylsiloxane (PDMS), polyethylene glycol (PEG), and acrylic acid (AA) and PDMS(-PEG-AA)-based copolymer have been conducted using mixed bacterial cultures (activated sludge) for up to one month under aqueous environmental conditions. Composting of PDMS and PDMS-based copolymers has been conducted to see microbial growth. Very limited biodegradation has been observed in aqueous environment but fungal growth has been observed under composting environment.

Dimuthu Wijeyaratne

The aim of this study was to develop multi-element fingerprints of the Souris River and Turtle River sediments and to evaluate the suitability of these fingerprints to assess the geographic origin of potential pollutants of the two rivers. This study provides a detailed analysis of element concentrations along the Souris and Turtle Rivers in North Dakota and provides information about relative sediments and element loading rates from the tributaries to the main rivers. Also this study helps to identify the sources and sinks of potentially enriched elements in the two rivers. The multi-element fingerprinting technique can be successfully used as a tool to identify the relative contribution of sediments and assessing and tracing pollution sources in rivers. Multi-element finger-printing provides a relatively low cost, rapid tool for sediment tracking, without the need for addition of exotic chemicals such as radio-tracers or dyes to natural ecosystems. The differences in the contribution of these elements were related to the underlying geology and the size of the watersheds.

Halis Simsek

Recent advances in the treatment processes and increasingly demanding regulations require the reduction of dissolved organic nitrogen (DON) portion of total dissolved nitrogen (TDN) in the wastewater effluent. Removal of biodegradable portion of DON (BDON) through biological treatment processes can contribute to effluent DON reduction. In this study, fate and characteristics of DON and BDON through a two-stage trickling filter wastewater treatment plant in Fargo, North Dakota were investigated. A season effect (summer, April to October versus winter, November to March) on the BDON profile was examined. Overall, the plant achieved higher BDON removal during the winter months. Modeling the fate of DON and BDON through the plant was attempted. The Biowin modeling process was selected and calibrated with the comprehensive data collected. Simulation of ammonia, DON and BDON through the plant showed perfect matching between the model results and the measured values. The model was found to be most sensitive to dissolved oxygen and particulate organic nitrogen hydrolysis rate. The model could potentially be used to optimize operational and control parameters of the plant to achieve better DON and BDON removal performances.

Harjyoti Kalita

Arsenic contamination of drinking water is a serious environmental and health concern. There is a need to develop cost effective solid phase extraction media which can be reused for a number of times using less technology intensive regeneration process. Also there is a need for an effective method to remove both As(III) and As(V) species. Ion imprinted polymers (IIP) are potential candidates to achieve these needs. These are cheaper, environmentally compatible, and have high selectivity relative to the conventional solid sorbents. In this study, Thiol- arsenic complex has been synthesized and combined with sodium arsenate as a source of As(V). A solid white colored thiol- arsenic complex compound was formed. Binding of aresic allyl mercaptal was seen from the FTIR spectra analysis. The solid white colored complex formed was imprinted in styrene-divinyl benzene copolymer. The copolymer was dried and leaching studies were conducted. ICP-OES analysis was carried out to see the binding and elution of arsenic to/from the polymer during the synthesis of the IIP of arsenic. More than 99 % arsenic was bound to the allyl mercaptan. A technique to synthesize IIPs for aqueous arsenic removal has been successfully developed.

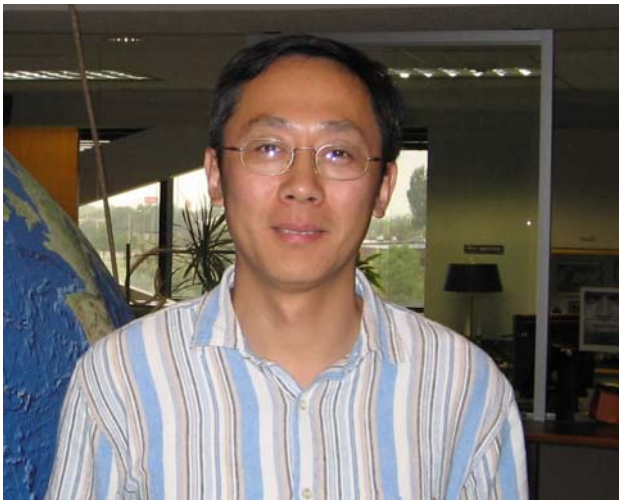
Qigang Chang

The goal of this research is to develop a method to synthesize GAC-Fe adsorbents for the removal of arsenic from groundwater to meet the current stringent arsenic standard in drinking water at an affordable cost for small rural communities in North Dakota. The multi-step iron impregnation method was modified to improve the impregnation efficiency and the arsenic adsorption properties. Using GAC Darco 20×50, iron content 28.90% (by weight) of iron was successfully impregnated inside GAC stably and evenly. This modification improved the impregnation efficiency approximately 100%. A new second-order kinetics model was developed to investigate the impact of the amounts of impregnated iron on arsenic adsorption kinetics. This new kinetics model can well fit arsenic adsorption kinetics. With iron content increase from 1.64% to 28.90%, the intrinsic adsorption rate constants kept reducing from 4.6×10-2 1/hr to 1.18×10-3 1/hr, which indicates that impregnated iron slows arsenic intraparticle diffusion rate in Fe-GAC. Decreased arsenic intraparticle diffusion rate was most likely caused by reduced pore size of Fe-GACs. The intrinsic adsorption rate constant is independent on initial arsenic loading in kinetics tests.

Ishara Rijal

This research is focused on the evapotranspiration. Evapotranspiration (ET) for both subsurface drained and undrained fields has been evaluated for soybean in 2010. The crop coefficient has been also developed. The reference evapotranspiration has been estimated using ASCE-EWRI 2005 and Jensen Haise methods. The reference evapotranspiration (ET_{ref}) was estimated using ASCE-EWRI 2005 (both grass and alfalfa) and Jensen-Haise 1963 methods. The ASCE-EWRI method is considered as the standardized and recommended method, while the Jensen Haise (JH) method is the most widely used method in North Dakota. The ASCE-EWRI method estimated a higher ET_{ref} compared to the JH method. The JH method underestimated the ET values especially during the windiest period in May, October and November. However, during mild wind conditions, the ET_{ref} rates by the JH method were comparable to that by the ASCE-EWRI (grass) method. Crop coefficient (K_c) was calculated for soybean under two different field conditions. The K_c was developed using the ET from the eddy covariance system and the ET_{ref} estimated using ASCE-EWRI (alfalfa) method. The soybean K_c curve had its highest values 0.76 for the SSD and 0.65 for the UD in July, representing the highest water demand by soybean during that period. During the early and late growing seasons, the K_c values were about the same in both fields.

Featured Institute Researchers



Dr. Xiaodong Zhang is an Associate Professor in the Department of Earth System Science and Policy at the University of North Dakota. He has a B.S. degree in Computer Science from Nanjing University, China and M.S. and Ph. D. degrees in Oceanography from Dalhousie University, Canada. Prior to working at UND since 2002, Dr. Zhang worked at the Ocean Remote Sensing Institute at the Ocean University of China from 1989 – 1996 as a remote sensing researcher and spent one year as a visiting researcher at School Marine Science and Technology, Tokai University, Japan. Dr. Zhang teaches graduate courses including Hydrological Cycle, Earth System Modeling and Aquatic Optics. A new course under preparation is Principles of Environmental Physics.

Dr. Zhang's research interest is in the area of modeling and observing radiative transfer of light in the Earth system and their inversion of environmental parameters, particularly those associated with water. One of his current studies is to infer the detailed information about particles in the ocean from the measurement of angular distribution of light. Extending his passion in oceanography to the heartland, Dr. Zhang is currently leading a NASA-funded project on developing a distributed hydrological model for the Devils Lake watershed and applying NASA satellite observation and future climate predictions to evaluate the water level variability. A complementary project that will be finished in the summer of 2011 is to deploy a buoy system providing real-time monitor of the water quality in the Devils Lake. Another new research area is to use scintillometry to measure sensible and latent heat fluxes across the surfaces to validate satellite observation. Research by Dr. Zhang and his students is mainly funded by NASA, with other supports from US Department of Agriculture and Office of Naval Research.

Dr. Zhang has one student that was recently awarded a NDWRRI fellowship: Kate Overmoe (Ph. D candidate). Kate's research is to assess the water quality of Devils Lake and other North Dakota's water bodies using Landsat imagery.

Dr. Zhulu Lin is an Assistant Professor in the Agricultural and Biosystems Engineering Department at North Dakota State University (NDSU), Fargo, where he has been establishing a program of research on Environmental Modeling & Sustainability. This program addresses core issues of developing and applying models in understanding and managing agricultural, hydrological, and environmental systems, with special reference to system identification, time-series analysis, and the analysis of uncertainty. Dr. Lin's current research focuses on assessing the potential impact of climate change and subsurface drainages on water resources in the Red River of the North basin. He and his students are also working on a project aimed at characterizing and managing land salinization in Yinchuan Plain, China, through an integrated framework of remote sensing and cellular automata - Markov chain model. Dr. Lin is also involved in an international researchers' collaboration network on "Cities as Forces for Good" and is currently a member of UNESCO's Working Group on Promoting Best Practices of Sustainable Urban Water Management.

Dr. Lin received his bachelors and masters degrees in Environmental Engineering from East China University of Science and Technology in Shanghai. He holds a masters degree in Statistics and a doctorate in Environmental Systems Analysis from the University of Georgia. Having worked in academia, industry, consultancy, and governmental agencies, Dr. Lin holds a 360-degree view on human-nature interactions and a unique angle to address sustainability problems through a systems approach.

Dr. John McEvoy is an Assistant Professor of Microbiology in the Department of Veterinary and Microbiological Sciences at North Dakota State University. He received his Ph.D. degree in Microbiology from the University of Ulster, Northern Ireland in 2002 before joining NDSU as a postdoc in 2003. He joined the faculty of Veterinary and Microbiological Sciences in 2004.

Dr. McEvoy carries out basic and applied research focusing on environmentally and medically relevant microorganisms. His lab primarily focuses on *Cryptosporidium*, a parasite that causes a diarrheal disease called cryptosporidiosis. *Cryptosporidium* is found in the feces of infected animals and humans and is easily spread in water due to its resistance to chlorine and other disinfectants. As a result, drinking and recreational water associated cryptosporidiosis cases occur each year in the United States; many of them in North Dakota and Minnesota. Funded by the USDA, Dr. McEvoy collaborates with Drs. Mark Clark, Eakalak Khan, and Xuefeng (Michael) Chu to study the source, fate, and transport of *Cryptosporidium* in rural watersheds. The group uses molecular tools to determine whether *Cryptosporidium* in local rivers originates from human, agricultural, or wildlife waste. For example, during recent flooding of the Red River, the group showed that *Cryptosporidium* contamination originated from both cattle and wildlife. Brianna Stenger is a North Dakota Water Resources Research Institute (NDWRRI) graduate fellow working on this project under the supervision of Dr. McEvoy and Dr. Clark. In other research, Dr. McEvoy studies how *Cryptosporidium* invades host cells to cause disease, supported by the NDSU Center for Protease Research. Dr. McEvoy also works with Dr. Khan on projects relating to bioremediation and, more generally, the interactions of bacteria with environmental pollutants.

Dr. Shawn DeKeyser is an Associate Professor in the School of Natural Resource Sciences, Range Program, and North Dakota State University. He received his B.S. in biology at Jamestown College in Jamestown, North Dakota. He then went on to pursue a M.S. degree in the Animal and Range Department at NDSU where he studied systematic botany. He finished his PhD research on wetland plant community assessment of Prairie Pothole wetlands in North Dakota in the Animal and Range Department at NDSU in 2000. Shawn was hired as a research specialist within the Department and continued his research in wetland assessment. In 2007, he was hired as an Assistant Professor in the SNRS, Range Program, with 65% research and 35% teaching responsibilities. He teaches a course in wildland plant identification. He also teaches two courses which he developed, one in rangeland planning, and the other in wetland resources management.

Dr. DeKeyser's research areas include fire ecology, invasive species, wetland restoration, riparian assessment, and riparian woodland restoration. His primary research area is still wetland assessment, and he is currently in charge of a statewide wetland assessment project that entails water, soil, and plant analysis that is being conducted by two M.S. students, two PhD students, a post-doctoral researcher, and three other faculty at NDSU. One of the PhD students is the recipient of a North Dakota Water Resources Research Institute Fellowship, and she is specifically comparing wetland assessment techniques and modeling ecosystem services provided by North Dakota's wetlands.

Recent Publications and Presentations by Institute Fellows and PIs

Book Chapter

Beck, M.B., **Z. Lin**, and J.D. Stigter (2011). Model structure identification and the growth of knowledge. In: Wang, L., and Garnier, H. (Eds.), *System Identification, Environmental Modelling and Control Systems*. Springer (in press)

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Bezbaruah, A.N.; Kalita, H. Sensors and Biosensors for Endocrine Disrupting Chemicals: State-of-the-Art and Future Trends in *Treatment of Micropollutants in Water and Wastewater* (Eds: Virkutyte, J., Varma, R.S., Jegatheesan, V.), International Water Association, London, U.K., pp. 93-115, 2010, ISBN: 9781843393160.

Carrie L. John, Shuping Xu, **Yuhui Jin**, Shaina L. Strating, and **Julia Xiaojun Zhao**, Synthesis and Applications of Gold Nanorods, *Trace Analysis with Nanomaterials*, Edited by David T. Pierce and Julia Xiaojun Zhao, Wiley-VCH**, 2010**, 359-381

Chang, Q.G.; Lin, W.; Ying, W.C. (2010) Preparation of iron-impregnated granular activated carbon for arsenic removal from drinking water. *J. Hazard. Mater. 184*, 515-522.

Derby, N., **F. Casey, T. DeSutter**, and H. Hakk. 2011. Effects of composting swine manure on nutrients and estrogens. Soil Sci. 176:91-98.

DeSutter, T., L. Prunty, and J. Bell. 2011. Concrete grinding residue characterization and influence on infiltration. J. Environ. Qual.40:1-6.

Hanson, A., Kittilson, J.D., McCormick, S.D., **Sheridan, M.A.**, 2011. Effects of 17β-estradiol, 4- nonylphenol, and β-sitosterol on the growth hormone-insulin-like growth factor system and seawater adaptation of rainbow trout (*Oncorhynchus mykiss*). Aquaculture, *in press*.

Lin, Z. (2011). Estimating water budgets and vertical leakages for karst lakes in north-central Florida (USA) via hydrological modeling. *Journal of American Water Resources Association* (JAWRA) 47(2):287-302.

Mary C. Schuh, **Francis X.M. Casey**, Heldur Hakk, **Thomas M. DeSutter**, Karl G. Richards, **Eakalak Khan** and Peter G. Oduor. Effects of Field-Manure Applications on Stratified 17β-Estradiol Concentrations. Journal of Hazardous materials, doi:10.1016/j.jhazmat.2011.05.080, Available online 1 June 2011

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Murthy Kasi, **John McEvoy**, **G. Padmanabhan**, and **Eakalak Khan** (2010) Groundwater Remediation Using Enricher Reactor - Permeable Reactive Biobarrier for Periodically Absent Contaminants, Water Environment Research, Accepted WER 10-09-2109R

Padmanabhan, G. and Brent H. Johnson (2010) Regional Dimensionless Rating Curves to Estimate Design Flows and Stages, Journal of Spatial Hydrology Vol.10, No.1 Spring 2010.

Ratpukdi, T; Casey, F; DeSutter, T; and Eakalak Khan. (2011). Bromate Formation by Ozone-VUV in Comparison with Ozone and Ozone-UV: Effects of pH, Ozone Dose, and VUV Power. J. Environmental Eng. 137, 187 (2011); doi:10.1061/(ASCE)EE.1943-7870.0000313

Song Liang, Carrie L. John, Shuping Xu, Jiao Chen, **Yuhui Jin**, Quan Yuan, Weihong Tan, and **Julia X. Zhao**, Silica-Based Nanoparticles: Design and Properties, Springer Series on Fluorescence, Advanced Fluorescence Reporters in Chemistry and Biology II, Edited by Alexander Demchenko, Springer, **2010**, 229-252

Suman L. Shrestha, Xuelian Bai, David J. Smith, Heldur Hakk, **Francis X. M. Casey**, Gerald L. Larsen, and **G. Padmanabhan** (2010) Synthesis and characterization of radiolabeled 17β-estradiol conjugates, Journal of Labelled Compounds and Radiopharmaceauticals, Published online in Wiley Online Library, DOI: 10.1002/jlcr.1864

Zhaosheng Fan, **Francis X. M. Casey**, Heldur Hakk, Gerald L. Larsen and **Eakalak Khan**.(2011) Sorption, Fate, and Mobility of Sulfonamides in Soils. Water, Air, & Soil Pollution, Volume 218, Numbers 1-4, 49-61, DOI: 10.1007/s11270-010-0623-6

Zitnick, K.K., N.W. Shappell, H. Hakk, **T.M. DeSutter, E. Khan, and F.X. Casey**. 2011. Effects of liquid swine manure on dissipation of 17β-estradiol in soil. J. Haz. Mat. 186:1111-1117.

Conference Proceedings

Chang, Q.G.; Lin, W. (2010) Impacts of amount of impregnated iron in granular activated carbon on arsenic adsorption capacities and kinetics. Proc. of 83rd WEFTEC, New Orleans, Louisiana, U.S.A., 282-299.

Hanson, A. and Sheridan, M.A. Effects of Environmental Estrogens on Organismal Growth and the Growth Hormone-Insulin-Like-Growth Factor System of Rainbow Trout. Annual Meeting of the Society for Integrative and Comparative Biology, Salt Lake City, UT, January 4-7, 2011.

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Wijeyaratne, Dimuthu Nilmini, Ph.D., Program of Environmental and Conservation Sciences, College of Graduate and Interdisciplinary Studies, North Dakota State University, March 2011. Multi-element Fingerprinting of River Sediments to Identify Diffuse Pollution Sources. Major Professor: **Dr. Marinus Otte.**

Chang, Qigang, Ph.D., Environmental and Conservation Sciences Program, College of Graduate and Interdisciplinary Studies, North Dakota State University, August 2011. Iron-Impregnated Granular Activated Carbon for Arsenic Removal from Drinking Water. Major Professor: **Dr. Wei Lin.**

Rabiya Shabnam, M.S., Environmental and Conservation Sciences Program, College of Graduate and Interdisciplinary Studies, North Dakota State University, August 2011**.** Interactions of iron nanoparticles with microorganisms**. Major Professor: Dr. Achintya Bezbaruah.**

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Watch out, nano tsunami on its way!

by Achintya Bezbaruah, Assistant Professor, Civil engineering department, North Dakota State University

Nanotechnology is influencing our lives in all fronts. Now we have tennis balls made with nanomaterial that last longer, golf balls that fly better, and bowling balls which are harder. Sunscreens, ski wax, car wax, and sanitizers available in the market use a variety for nanoparticles including titanium, zinc, and silver. There are strain resistant textiles because they are hydrophobic, and socks wouldn't stink because they contain bacteria killing nanoparticles. The next generation computer chips will help us fabricate faster, smaller and more efficient computers. Flat screen televisions will cost less, and we will have more efficient insulation materials, car batteries, efficient energy production units, and sensors which will be used in automobiles, airplanes, and within the human body. The United States Army plans to use carbon nanotubes for a new generation of concrete, steel, and ceramics for military and civilian infrastructures. Carbon nanotubes are 150 times stronger than conventional steel! Doctors can now deliver target specific medicines to the affected organs or body part with nanoparticulate drug delivery vehicles. These vehicles carry and deliver drugs to the cancerous tumors, and thousand times lower dose of chemotherapy medicine is used as there are minimal losses. Toothpastes containing nanocomposites will soon be used to 'self heal' dental cavities! Scientists are experimenting with a process called 'self assembly' where nanomaterials will be kept together under the ideal conditions and they will start assembling together to form a bigger material (a human organ).

New developments always have negative impacts. When nuclear energy, synthetic chemicals, and electronics were introduced, the excitement overshadowed the concerns and we didn't care to look at the darker sides. We have learned the hard way from such neglects, but we are better prepared and careful now. Scientists have studied the not so bright side of nanotechnology too. Nanomaterials are found to impact human and other species like fish and insects. Human lungs are affected by reactive nanoparticles. In fish, nanoparticles are found to accumulate in their bodies and affect their brains. Environmental microbiologists are worried that uncontrolled release of nanoparticles may wipe out the whole population of useful bacteria present in the environment.

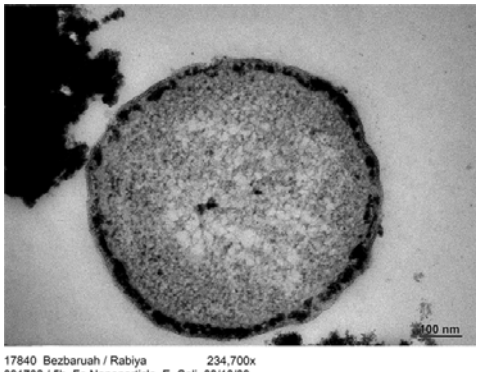
Civil Engineering Department's Nanoenvirology Research Group (NRG) at North Dakota State University looks into effects of nanomaterials on the environment in addition to exploring possible novel uses of nanomaterials for environmental pollution control. In a recently concluded research funded by North Dakota Water Resources Research Institute (NDWRRI), NRG members have discovered that endemic bacteria are affected by iron nanoparticles but the bacteria have certain mechanisms to overcome the toxicity. Also, actively growing bacteria are not affected by the particles. Another NDWRRI-funded project is presently experimenting with a combined system of nanoparticles and trichloroethylene (TCE) degrading bacteria to create a more efficient remediation technique where bacteria and iron nanoparticles will complement each other in remediating toxic chemicals. Arsenic is a very toxic metalloid present in our drinking water. NDWRRI has funded a few projects by NRG to remediate arsenic in water. The group is using iron-based nanoparticles coated with biopolymers to adsorb arsenic. In another research project, a novel reusable nanoporous polymer has been synthesized which will specifically capture arsenic present in water. Advanced techniques for arsenic removal are needed to treat drinking water to the United Stated Environmental Protection Agency's standard of 10 micrograms of arsenic per liter. The research group from NDSU has also filed applications for final patent rights for a polymer-based 'vehicle' (or coating) which will deliver nanoparticles to contaminated aquifer sites. This delivery vehicle is expected to find applications in drug and nutrient delivery in human and plants too. In a most recent project, researchers in the group have used nanoparticles to recover phosphate from polluted water. Phosphate is an essential nutrient for plants

Continue from page 10

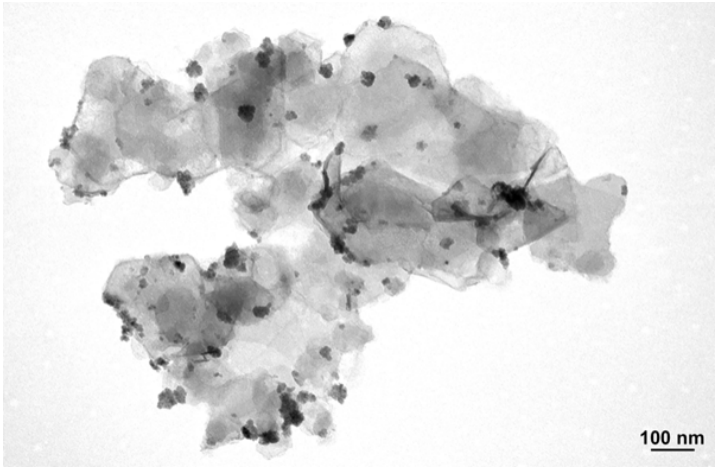
(wheat, soybean, and corn) and applied to plants in the form of fertilizers. Presently phosphorus is mined to make phosphate but the supply will be in the decline from 2035 or so. Phosphorous also causes eutrophication of lakes and other fresh water bodies. The present project will not only find a solution to the eutrophication problems but also create a new way to 'mine' phosphate through effective recovery.

NDSU Nanoenvirology Research Group

Biopolymer encapsulated iron nanoparticles



Electron microscope image of a cross-section of bacterial cell that the bacteria either adsorb or internalize the iron nanoparticles



Polymeric delivery vehicle for nanoparticle for which the NDSU research group has applied for final patent rights.

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Recent NDSWC Reports

WRI No 49 (20 mb) - Water Appropriation Requirements, Current Water Use, & Water Availability for Energy Industries in North Dakota: A 2010 Summary, Prepared by W.M. Schuh, August 2010.
(Note when printing this PDF: 10 map insert pages are 11" x 17" and may need to be printed separately.)

WRI No 49-A (3 mb) - Water Appropriation Requirements, Current Water Use, & Water Availability for Energy Industries in North Dakota: A 2010 Summary, APPENDIX, Prepared by W.M. Schuh, August 2010.

WRI No 50 [Main Report] (169 mb) - Analysis and Simulation of the Oakes Aquifer: An Assessment of Groundwater Availability, [Main Report, through p. 156], By R. L. Cline, 2011.

WRI No 50 [Appendix] (190 mb) - Analysis and Simulation of the Oakes Aquifer: An Assessment of Groundwater Availability, [Appendix, pp. 157-376], By R. L. Cline, 2011.

WRI No 52 (86 mb) - Hydrogeology and Groundwater Management in Northern Kidder and Northwestern Stutsman Counties, North Dakota, By Gordon M. Sturgeon, 2011.

ND WRRI 1st Distinguished Water Seminar

A new annual event "ND WRRI Distinguished Water Seminar" was instituted by the NDWRRI.

The purpose of the seminar series is to bring eminent professionals to North Dakota State University to talk about emerging issues, challenges, and new research directions in hydrology and water resources. The speaker for the inaugural seminar held on October 7, 2010 was Dr. Vijay P. Singh, a nationally and internationally well-known hydrologist. The topic was "Challenges, Opportunities, and Research Directions in Hydrology and Water Resources." Dr. Singh delivered another talk "Water Resources and Climate change" at University of North Dakota, Grand Forks. Both the talks were well-attended by faculty and students working in water-related research. The seminar was co-sponsored by the ND Water Resources Research Institute, the Environmental and Conservation Sciences Graduate Program, the Agricultural and Biosystems Engineering Department, and the Civil Engineering Department, NDSU.

Dr. Vijay Singh and Dr. Gregg Wiche (USGS and ND WRRI advisory committee member) discuss water issues

Mr. William Schuh (ND State Water Commission and ND WRRI advisory committee member (left) with Dr. Dean Steele (NDSU Agriculture and Biosystems Engineering faculty) (middle) with Dr. Vijay Singh

WRRI co-sponsored a presentation on F-M Diversion

Dr. Ed Dickey, former acting assistant secretary of the army for civil works, Washington, D.C., shared his insights on federal water projects on Wednesday, Jan. 12, at 11 a.m. in the Memorial Union Century Theater. Dr. Dickey focused on the Washington perspective on F-M diversion project.

While working for the federal government, Dr. Dickey was responsible for a variety of policies and programs related to federal water management activities, including new water resource investments for navigation, flood damage reduction and ecosystem restoration. Two Presidential Rank Awards, including Meritorious Executive in 1988 and Distinguished Executive in 1993, acknowledged his successes as a member of the federal Senior Executive Service.

NDSU's School of Natural Resources, Department of Agribusiness and Applied Economics, Environmental and Conservation Sciences Graduate Program and the North Dakota Water Resources Research Institute sponsored Dr. Dickey's presentation.

Achintya Bezbaruah, ND WRRI Institute affiliate faculty , guides junior high school students to win NASA award

Achintya Bezbaruah, an affiliate faculty of North Dakota Water Resources Research Institute, advised a group of junior high students from West Fargo High School on a project that took first place out of more than 300 teams in the nationwide Waste Limitation Management and Recycling Design Challenge organized by NASA. The competition was to design a system that will convert human urine and wastewater into drinkable water to reduce future lunar settlers' dependence on the Earth. Bezbaruah says it costs about $22,000 to transport one liter of water from the Earth to the moon. The team devoted more than 800 research hours to come up with the winning design concept. The College of Engineering and Architecture, North Dakota State University, sponsored the project.

The students tested activated carbon, zeolites, ion□exchange resin, baking soda, vinegar and experimented how simple storage can remove ammonia from water. They estimated the wastewater treated using their winning system will cost $2,000 per liter.

As the top design team in the country, the students and Bezbaruah received an all-expense paid trip to the Kennedy Space Center in Florida where they met with NASA experts, enjoyed VIP tours, witnessed the last launch of Space Shuttle Atlantis to the International Space Station.

North Dakota Water Commission 2011-13 Strategic Plan now available

This new Strategic Plan contains descriptions and overviews of the agency's major projects and programs.
http://swc.state.nd.us/4dlink9/4dcgi/GetSubCategoryPDF/43/SratPln20112013.pdf

Governor Dalrymple Proclaims *Drinking* Water Week

North Dakotans Encouraged To Protect and Conserve the State's Waters
http://www.ndhan.gov/data/mrNews/Drinking%20Water%20Week%202011.pdf

State Health Department Urges Private Well Owners To Take Precautions During Flooding

http://www.ndhan.gov/data/mrNews/PrivateWells_Flooding2011.pdf

Bismarck/Mandan Groundwater Maps

Released June 9th, 2011 is a revised May 31 depth to water table map using a more extensive data set that includes gate valve box water level |elevations provided by the city of Bismarck, and water level data measured at commercial observation wells. In addition, a new depth to water table map based on water level elevations measured on June 6th is provided.

The Mandan map is based on a very limited number of observation wells. The water table elevation map is dominated by the elevations of the Missouri and Heart Rivers and the elevation of Marina, Border Harbor, Lakewood, and Bridgeview bays. The water table is likely deeper in many areas than is shown on the map. Water-level elevations will be measured at gate valve boxes and additional observation wells to be installed in the very near future. The more comprehensive water-level monitoring network will greatly improve future versions of the map.

Devils Lake Technical Review Report Released

A NEW Report of the Devils Lake Basin Technical Review Team was recently released. The purpose of the report is to outline potential "next steps" to addressing the continuing flooding problems in the Devils Lake basin. The report was developed through a cooperative effort of the ND State Water Commission, the ND Department of Emergency Services, and the U.S. Army Corps of Engineers.

http://swc.state.nd.us/4dlink9/4dcgi/GetSubContentPDF/PB-2093/2010%20Report%20of%20the%20Devils%20Lake%20Basin%20TRT%20Final.pdf

Flood website provides information

A website that evolved from an NDSU course project provides important information about the flooding in the Minot, N.D., area. The site, "Mouse River Flood 2011," allows anyone to report flood-related photos and observations. It came from work in the Comparative Programming Languages computer science course taught by Anne Denton, associate professor of computer science. The site contains a map of the area, and regularly updated photographs contributed by the public for specific locations in the Minot community.

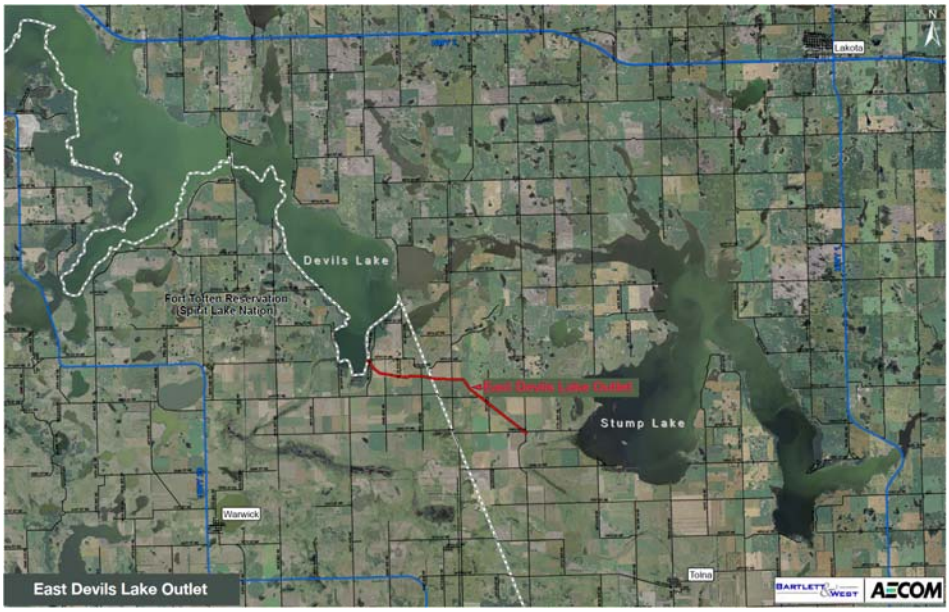
Paul Loree, a computer science instructor at Minot State University and also a graduate student at NDSU, has taken the lead in adapting the site to Minot conditions. He said the site tries to make information sharing as quick and easy as possible. According to Loree, site visitors can look up an address for the area they want to see or they can create a marker for an address if they have information or a photo regarding that address.

This website could help reduce the anxiety level of people not knowing what is happening around their homes in the flood area.
The site, which also incudes links to North Dakota National Guard photos and videos, can be found at http://mouseriverflood2011.net/index.php.

State Moving Forward on East Devils Lake Outlet

Governor Jack Dalrymple announced in early March that the state has selected a project plan to build a second water outlet at Devils Lake.

The project, developed by the State Water Commission, calls for constructing an underground pipeline from East Devils Lake to the downstream side of Tolna Coulee (see map). The pump-flow pipeline will be capable of transferring between 250-350 cfs from Devils Lake into the Sheyenne River. The project is scheduled for completion in the spring of 2012, and is expected to cost between $62 million and $90 million. The East Devils Lake outlet project was developed in collaboration with area stakeholders including the city of Devils Lake, the Ramsey County Commission, the Spirit Lake Nation, and Valley City. The current west-end outlet will continue to operate again this summer. With the existing 250 cfs west end outlet in place, a 250 cfs east end outlet, and a 100 cfs west end expansion, the state could be releasing up to 600 cfs via outlets in the coming years.



State Water Commission Funds Rapid Deployment Gages

Following the 2009 flood, it became apparent that it would be of great value to have additional streamflow information in critical ar-eas that could be accessed in a timely manner. In the past, when additional streamflow information was needed in areas where there were no existing gages, or when emergency condi-tions required more detailed moni-toring, the United States Geologi-cal Survey (USGS) has used rapid deployment gages - when they were available. In many instances, these types of gages have proven to be valuable and flexible in flood forecasting and response.

Unfortunately, the USGS has not always had enough rapid deployment gages available, as their inventory is used throughout the country. After the floods of 2009, funds were made available for flood miti-gation grants through the Federal Emergency Manage-ment Agency (FEMA). To avoid the issue of not having gages available in North Dako-ta as needed, Water Commis-sion staff prepared an application for funding to purchase six rapid deployment gages. The Commission's application was ultimately approved, and the USGS ordered the six gages. Dur-ing this year's spring flooding, the six gages were installed at Burling-ton, Minot, Logan, Bea-ver Creek (below Jamestown), the Highway 46 crossing of the Sheyenne River below Kathryn, and the James River near Manfred. In addition to the six new gages purchased by the Commission, the USGS deployed ten other short-term stream gages throughout the state in critical areas needing additional monitoring during the spring of 2011. The total cost of the six gages was $65,830. Un-der the grant pro-gram they were funded through, 75 percent of the funds were provided by FEMA, 10 percent by North Dakota's Depart-ment of Emer-gency Services, and the remaining $9,875 was paid by the Commission.

Fate and transport of estrogenic and androgenic reproductive hormones in soil-water systems

by Francis Casey, Interim Chair, Agriculture and Biosystems Engineering and Professor of Soil Science, North Dakota State University

Reproductive hormones in the environment are potent at extremely low concentrations. For example the natural estrogen, 17β-estradiol (E2), can bind to hormone receptor sites in a body and induce disruptions in the endocrine system. Male rainbow trout will start expressing female proteins for egg yolks at E2 concentrations between 1 and 10 parts per trillion. Analogously, 10 parts per trillion would be about six feet in a journey from the earth's surface to the sun.

The issue of reproductive hormones in the environment is of particular relevance to animal feeding operations (AFOs). Although all species, sexes, and classes of mammals eliminate estrogenic hormones into the environment, the potential environmental loading by AFOs is far greater compared to humans. Estimated annual contributions from AFOs in the U.S. alone are approximately 1.7 times greater compared to the entire 6.9 billion global human population.

In 2002, the USGS published a survey of 139 rivers water samples taken downstream AFOs and waste treatment plants. This study detected E2 and other reproductive hormones in 40% of their samples, and several of the concentrations were high enough to cause reproductive anomalies in aquatic organisms. Subsequent studies have detected reproductive hormones in surface and subsurface water that have been impacted by animal agriculture.

For the past decade, a group of researchers at NDSU and the Animal Metabolism–Agricultural Chemical Unit (AMACU) of the USDA-ARS have focused their research on this relevant issue. This group was the first, nationally and internationally, to identify the fate and transport of estrogenic and androgenic reproductive hormones in laboratory studies. They have also applied their laboratory results to try to explain field observations, particularly in how manure management affects hormone fate and transport.

The NDSU/AMACU group found reproductive hormones to be quite labile in laboratory, where they readily degrade and bind to soil within hours to a few days. In contrast to these laboratory results, field experiments and observations indicated estrogenic reproductive hormones are wide-spread. This research group detected estrogens in surface and subsurface water, and distributed throughout field soil profiles.

Current research by the NDSU/AMACU research group is focusing on how to explain the seemingly disparate results between laboratory and field studies. Recent results indicate reproductive hormones will preferentially associate with colloidal materials in the soil or manure, which then can facilitate the hormone's mobility on and through soil. Additionally, the association of the hormones to the colloids could possibly enhance the persistence of hormone in the soil and water. Researchers in this group have also started to identify the role that hormone conjugates play in the facilitated transport of hormones in the environment. To eliminate hydrophobic hormones from their body, animals enzymatically conjugate sugars or sulfates to the hormone molecule, increasing the solubility for urinary excretions. More than half of the reproductive hormones excreted by mammals are in this conjugated form. Once in the environment, the sugar or sulfate can deconjugate transforming back to the potent reproductive hormone. Initial results from the NDSU/AMACU research group indicate hormone conjugates may play a major role in the overall fate and transport and environmental loading of reproductive hormones in the environment.

Biosensor for Monitoring of Mercury Pollution in Natural Waters

by Julia Xiaojun Zhao, Associate Professor, Department of Chemistry, University of North Dakota

Mercury is a very toxic element that is widely spread in the atmosphere, lithosphere, and surface water. Red River of the North is a major water source in the states of North Dakota and Minnesota. Mercury pollution has been a public concern in the Red River and other lakes in North Dakota since 1990. Due to its high toxicity, mercury is harmful even at a very low concentration (the maximum allowable level of mercury in drinking water is 2 ppb). Therefore, it is essential to develop a highly sensitive detection method for accurately monitoring mercury levels in the rivers and lakes. Our research group is currently engaged in developing a novel biosensor that can sensitively and selectively monitor mercury pollution in natural water.

The sensor will use rolling circle amplification (RCA) of DNA species. A weak signal could be enlarged by ten thousand times through this amplification. Therefore, even trace amounts of mercury in the water can be accurately detected. We expect that the sensor would have three major desirable features.

High Sensitivity.

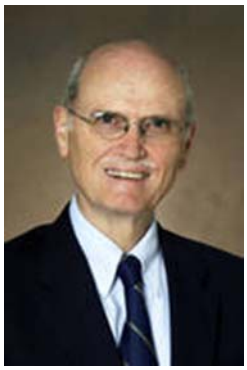
The design of the Hg^{2+} sensor is based on the two strategies of rolling circle amplification (RCA) and a repeatable usage of the limited Hg^{2+} in the solution, wherein both strategies can significantly amplify the signal and lower the detection limit.

High Selectivity.

The specificity of a sensor is an important parameter. The developed mercury sensor will produce signals only in the presence of Hg^{2+}. The high selectivity to mercury is from the ability of Hg^{2+} binding to T-T mismatch in a DNA sequence. The binding will stabilize the DNA duplex.

Rapid Detection. The RCA process can be completed in a very short time. Moreover, no pre-concentration steps are required in this Hg^{2+} sensor.

Former Director of ND WRRI, Dr. Gregory McCarthy, retires



Dr. Gregory McCarthy retired after 32 years of service to North Dakota State University. He served as director of the North Dakota Water Resources Research Institute from 1992 to 2001. Dr.McCarthy joined NDSU as professor of chemistry and geology in 1979, chair of the Department of Chemistry from 1993 to 2001, associate vice president for interdisciplinary research from 2001 to 2010, and as the founding director of the Center for Nanoscale Science and Engineering from 2002 to 2009.

Dr. McCarthy is credited with establishing the North Dakota Water Resources Research Institute Fellowship program as it is administered today. Every year about ten to twelve NDSU and UND students working in water-related research benefit from the Fellowship program.

At NDSU, McCarthy taught general chemistry, analytical chemistry and solid state chemistry courses in the chemistry department, as well as mineralogy, petrology and geochemistry in the geology department. He received numerous recognitions for his teaching.

Dr. Vijay Singh, the First ND WRRI Distinguished Water Seminar speaker

Dr. Gregg Wiche, (USGS), Mr. Charles Fritz (International Water Institute) and Dr. Vijay Singh on the banks of the Red River (left to right)

Dr. Vijay Singh (middle) with Dr. Xuefeng Chu (Civil Engineering, NDSU) . Dr. Xiadong Zhang (Earth Systems Science and Policy, UND), Dr. G. Padmanabhan (Civil Engineering, NDSU and Director ND WRRI) and Dr. Howe Lim (Civil Engineering, UND) (left to right)

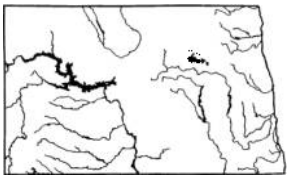
North Dakota Department of Health Water Quality Division Report:

North Dakota 2010 Integrated Section 305(b) Water Quality Assessment Report and Section 303(d) List of Waters Needing Total Maximum Daily Loads

Submitted to the US EPA
March 24, 2010

Approved by EPA
April 23, 2010

http://www.ndhealth.gov/WQ/SW/Z7_Publications/IntegratedReports/2010_Final_Approved_IntegratedReport_20100423.pdf



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Garrison dam spillways
http://talk.newagtalk.com/forums/thread-view.asp?tid=241451&mid=1833151

Water rushes out of Lake Darling on Friday, June 24, 2011.
Carrie Snyder / The Forum

North Dakota Water Resources Research Institute (NDWRRI)

The Institute was founded in 1965 by authority of Congress as one of the 54 Institutes throughout the nation and is administered through the United States Geological Survey. The NDWRRI receives funding through section 104 of the *Water Resources Research Act of 1984* and it applies its Federal allotment funds to research that fosters: A) the entry of new research scientists into the water resources field, B) training and education of future water resources scientists, engineers, and technicians; C) the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena; and D) the dissemination of research results to water managers and the public.