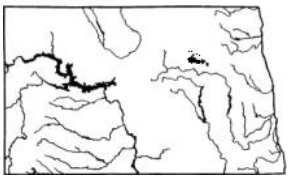
December 2016

North Dakota Water Resources Research Institute
North Dakota State University
Fargo, ND 58108-6050



Newsletter

The National Institutes for Water Resources

http://www.ndsu.edu/wrri

From the Director

Greetings and welcome to the 2016 issue of North Dakota Water Resources Research Institute (NDWRRI) newsletter! This is my second year as the Director of the Institute, which has continued to serve as resources to its stakeholders. The Institute has met mandates required by Section 104 of the *Water Resources Research Act of 1984* through several research, education, training, and outreach activities related to water issues in the State. Although it is a small part, this newsletter is one of those activities.

For the past few years, we have several new junior faculty with expertise related to water that have joined the two research universities in the State. They are considered Institute affiliated faculty. Three of them are featured in this newsletter in "Meet our Faculty" section. Other sections/ stories include retirement of Dr. G. Padmanabhan, the Former Institute Director, after serving NDSU for 36 years, introduction of the 2016 NDWRRI Fellows, and highlights of the 2015 Fellowship research projects. In addition, you will find lists of recent water related publications from the United States Geological Survey (USGS), State Water Commission (SWC) and the Institute, and stories on events participated by affiliated faculty and Fellows, and the 5th Annual Distinguished Water Seminar hosted by the Institute.

For 2016-17, the Institute has received full base grant funding from USGS and supplemental support from North Dakota SWC. The supplemental support from SWC has increased from 15% of the USGS base grant in the previous year (2015-16) to 20.4%. This shows a strong commitment from ND SWC in supporting research on water resources in the State. The entire supplemental support has been used to fund the Graduate Fellowships. The Institute would like to thank ND SWC for the support. The Institute has continuously received advices and help from the State Advisory Committee consisting of Gregg Wiche, USGS ND Water Science Center; William Schuh, ND SWC; and Peter Wax, ND Department of Health. Their valuable guidance especially on Institute's research priorities, Fellowship funding allocation, and assistance in securing support from ND SWC contributes to the success of the Institute.

Water is a vital resource for the growth and development of North Dakota. It is indispensable for vibrant agriculture and industry sectors of the State as well as municipal/domestic consumptions. The Institute is committed to support research, education, training, and outreach that are beneficial to water resources in the State.

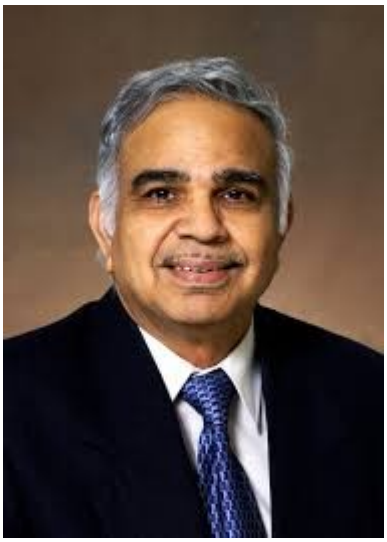
Thank you for your interest in the Institute and for some of you for being part of it. Please enjoy the newsletter.

Best wishes,

Eakalak Khan

Inside this issue:

ND WRRI Past Director Retires from NDSU



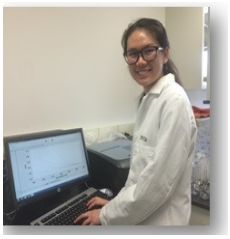
G. Padmanabhan, Ph.D., P.E., F. ASCE

Past Director, ND Water Resources Research Institute (2001– 2014)
Professor Emeritus, Civil and Environmental Engineering, NDSU

Dr. G. Padmanabhan served as the Director of NDWRRI for 13 years. He was appointed on October 1, 2001 while he was serving as the Chair of the NDSU Department of Civil and Environmental Engineering. His contributions to NDWRRI were enormous and long -lasting. He enhanced the Graduate Research Fellowship (GRF) program while fulfilling the requirements of Section 104 of the Water Resources Act. His diligent endeavors led to the removal of the "probation status" of the Institute in year 2004. Approximately 200 graduate students benefitted from the fellowship program during his period as the Director. The faculty participation too increased from 2-3 to 12-15 faculty per year. In addition, interactions between faculty, industries and state agencies increased through to the Fellowship projects. The NDWRRI GRF program is now viewed by other Institutes as a successful model and worth emulating. Dr. Padmanabhan was an inspiring director and a great mentor to professionals, faculty and graduate students. His words of wisdom and politeness made him very approachable. The institute will strongly miss him and wishes him a very happy and healthy retirement life.

An open house was hosted for the retirement celebration of Dr. Padmanabhan on November 18, 2016 at NDSU. The event was attended by NDSU President, Provost, faculty, students and staff. A glimpse of the open house can be seen in the pictures below.

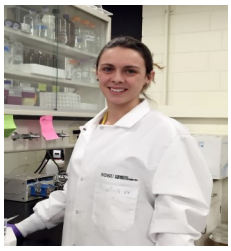
The Institute Awarded Fifteen Graduate Fellowships for the Year 2016-2017



Fellow: Boonsiri Dandumrongsin

Title: Contribution of Soluble Microbial Products on Dissolved Organic Nitrogen and its Biodegradability in Wastewater Effluent

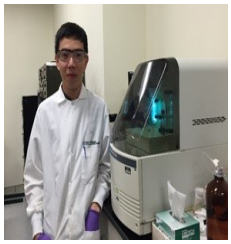
Advisor: Halis Simsek, Agricultural and Biosystems Engineering, NDSU



Fellow: Marina Martin

Title: Tamoxifen and Endoxifen Detections in Wastewater and Receiving Waters in North Dakota

Advisor: Eakalak Khan, Civil and Environmental Engineering and John McEvoy, Microbiological Sciences, NDSU



Fellow: Soklida Hong

Title: Glutaraldehyde Removal from Flowback and Produced Water Using Photolysis

Advisors: Eakalak Khan, Civil and Environmental Engineering and Jayaraman Sivaguru, Chemistry and Biochemistry NDSU

Fellow: Mohammad Hossain

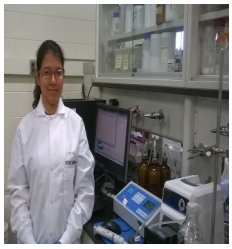
Title: Biopolymers for Phosphate Removal from Eutrophic Lakes

Advisor: Achintya Bezbaruah, Civil and Environmental Engineering, NDSU

Fellow: Alexis Steinman

Title: A Comparison of Wetlands across the Urban - Peri-Urban - Rural Gradien

Advisor: Christina Hargiss , Natural Resources Management, NDSU



Fellow: Umma Salma Rashid

Title: Injectable Nanoparticle-based Permeable Reactive Barriers for Groundwater Contaminant Remediation

Advisor: Achintya Bezbaruah, Civil and Environmental Engineering, NDSU

Fellow: Debjit Roy

Title: Snowmelt Water Infiltration into Frozen Soil in the Red River of the North Basin

Advisor: Xinhua Jia, Agricultural and Biosystems Engineering, NDSU

Fellow: Swati Sharma

Title: UV Light Effect on Bioavailability of Dissolved Organic Nitrogen in a Trickling Filter Process

Advisor: Halis Simsek, Agricultural and Biosystems Engineering, NDSU

Fellow: Bahareh Shoghli

Title: Design Parameters of Embankment Dams in the Upper Midwest in Potential Climate Change Conditions

Advisor: Yeo Howe Lim, Civil Engineering, UND

Fellow: Ursinio Puga

Title: Ultraviolet Disinfection Pilot Study at Fargo Wastewater Treatment Plan.

Advisor: Wei Lin, Civil and Environmental Engineering, NDSU

Fellow: Afshin Shabani

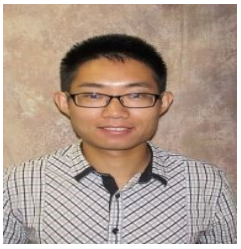
Title: Modeling Water Balance and Flows of Sediment and Nutrient in Devils Lake Watershed Using SWAT

Advisor: Xiaodong Zhang, Earth System Science and Policy, UND

Fellow: Tong Lin

Title: Assessing the Impacts of Hydraulic Fracturing at Bakken on Regional Water Resources

Advisor: Zhulu Lin, Agricultural and Biosystems Engineering, NDSU



The Institute Awarded Fifteen Graduate Fellowships for the Year 2016-2017

Fellow: Luisa Torres

Title: Risks of Water Contamination Associated with the Wastewater from Oil Production in the Bakken

Advisor: Eakalak Khan, Civil and Environmental Engineering and Om Yadav, Industrial and Manufacturing, NDSU

Fellow: Benjamin York
Title: Effect of Glacial Isostatic Adjustment on Rivers and Drainage Basins in the Red River Valley

Advisor: Phil Gerla, Geology and Geological Engineering, UND

Fellow: Courtney Jackson

Title: Assessment of Climate Change and Agricultural Land Use Change on Streamflow Input to Devils Lake: A Case Study of the Mauvais Coulee Sub-Basin

Advisor: Paul Todhunter, Geography, UND

Upcoming Events

American Water Works Association, Annual Conference & Exposition, Philadelphia, PA, June 11 - 14, 2017

Water Environment Federation, Nutrient Symposium, Fort Lauderdale, FL, June 12 - 14, 2017

Water Environment Federation Technical Exhibition and Conference (WEFTEC), Chicago, IL, September 30 - October 4, 2017

WaterSmart Innovations, Las Vegas, NV, October 4 - 6, 2017

Minnesota Water Resources Conference, St. Paul, MN, October 17 - 18, 2017

American Water Resources Association Annual Water Resources Conference, Portland, OR, November 5 - 9, 2017

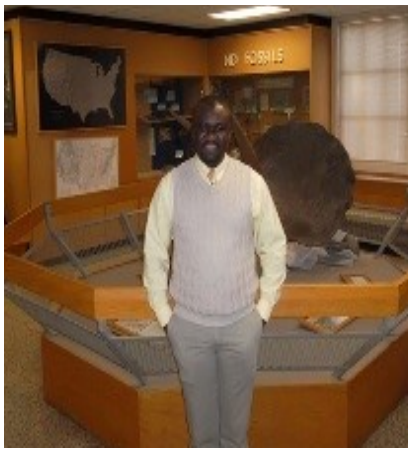
National Ground Water Association, Groundwater Week, Nashville, TN, December 5 - 7, 2017

2015 — 2016 NDWRRI Fellowship Research Highlights

Debjit Roy: Snowmelt Water Infiltration into Frozen Soil in Red River of the North Basin

In cold region hydrology, snow melting is a major event in seasonally frozen areas. Soils in the Red River of the North basin (RRB) remain frozen for specific seasons of the year. Infiltration into frozen soil is very different compare to unfrozen soil infiltration due to refreezing of or melting soil ices by infiltrating water. Frozen soil infiltration depends on dynamic relationships of phase changes of water, amount and distribution of ice contents in zone of infiltration (0-30 cm of soil profile), soil pore size distribution, soil temperature, freeze-thaw cycles and also hydraulic conductivity changes due to frozen soil temperature change. The lack of understanding of the infiltration process into frozen soil is the major limiting factor affecting spring flood forecasting in the RRB which includes huge costs for flood preparation in this region. The goals of this study are to investigate: frozen soils response to infiltration, soil properties effects on infiltration into frozen soils and hydraulic conductivity changes in frozen soils. Research work under four titles were planned to meet the specific objectives of the study. In one of the research works, nine long-duration infiltration experiments were conducted in the laboratory on a frozen silty loam soil for three initial soil moisture conditions: soil moisture at permanent wilting point (θ_{pwp}), soil moisture at field capacity (θ_{fc}) and soil moisture at halfway between PWP and FC ($\theta_{pwp} \leq \theta \leq \theta_{fc}$). Infiltration rate over time and soil volumetric water content (VWC) change with soil temperature were evaluated. The results showed that frozen soil infiltration rate over time relationships for three initial soil moisture conditions followed Horton's infiltration model with R^2 values of 0.91, 0.37 and 0.71, respectively. At 0°C temperature, VWC of soil increased rapidly due to the phase change of water from ice to liquid. VWC changes with temperature was smooth in θ_{pwp} compared to that in $\theta_{pwp} \leq \theta \leq \theta_{fc}$. Soil water release curve comparisons between soils before and after experiments showed that soil pore size distribution was changed due to freeze-thaw and soil packing events that may affect the hydraulic and thermal properties of soil.

Prosper Gbolo: Quantifying Phosphorus Cycling and Fate within an Abandoned Feedlot



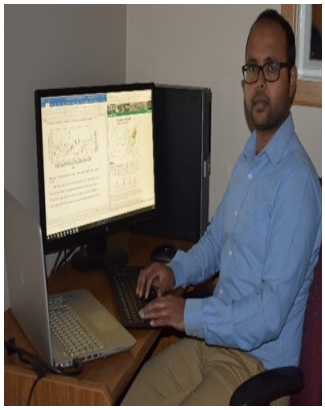
Nutrients, including nitrogen and phosphorus are important in various ecosystems, but when mismanaged can cause adverse health and ecological problems. It is hypothesized that nitrogen can cause a short-term contamination of soils and groundwater beneath feedlots, but phosphorus can cause both short- and long-term contamination in well-drained iron and calcium rich soils. To test this hypothesis, a feedlot abandoned more than a decade ago was used as a model for this research because of the existence of different soil types, apparent variable plant vigor, and the hydrological conditions prevailing. This research aims at determining the sources and sinks of nutrients, characterizing nutrients distribution, and quantifying phosphorus budget. Soil, groundwater, surface water, and plant tissue samples were collected and analyzed for nutrients. It was observed that nitrogen concentration was less at the source (feedlot pens) due to processes including denitrification, volatilization, leaching, and transportation in the wetlands characterized by high plant vigor. In contrast, phosphorus was sequestered in soils at the source area that had high organic matter, iron, and calcium content, making it unavailable for plant consumption. This research provides insight into the viability of feedlots abandoned more than a decade as a source of phosphorus to supplement the primary sources of phosphorus used in fertilizer. Phosphorus concentrations in some areas exceed 50 mg kg^{-1}, which implies no soil phosphorus fertilization is required for plant growth. Agronomists and stakeholders in agriculture and food security should take a holistic approach and conduct feasibility studies on using sequestered phosphorus in abandoned feedlot soils as alternative source of phosphorus fertilizer.

2015 — 2016 NDWRRI Fellowship Research Highlights

Mohammad Enayet Hossain: Biopolymers for Phosphate Removal from Eutrophic Lakes

Phosphorus (P) is important for the growth of plants and microorganisms in most ecosystems. However, when excess phosphorus stemming from point sources and non-point sources finds its way into waterbodies it leads to eutrophication. About 260,000 metric tons of PO_4^{3-}-P are discharged to US waters every year from wastewater treatment facilities. Agricultural run-offs constitute the major non-point sources for phosphorus. In the US, agriculture contributes ~3,629,000 metric tons of PO_4^{3-}-P per year to water bodies. Accelerated eutrophication due to high phosphate presence not only impacts the aquatic life but also hampers the economy of communities that rely on aquatic food and other resources. It has been estimated that $2.2 billion is lost annually as a result of eutrophication in U.S. freshwaters. The greatest economic losses were attributed to lakefront property values ($0.3-2.8 billion/year) and recreational use of waters ($0.37-1.16 billion/year). In this research, novel iron (Fe) cross-linked alginate (FCA) beads were used for aqueous phosphate removal. Batch experiments were conducted with the beads using three different concentrations of phosphate (5, 50 and 100 mg PO_4^{3-}-P/L) as well as environmentally relevant (eutrophic lakes) concentration of 100 µg PO_4^{3-}-P/L. About 80-97% phosphate was removed within 3 h. for lower concentrations of phosphate. The maximum phosphate sorption capacity was found to be 78.7 mg PO_4^{3-}-P/g of beads. Phosphate removal was not affected because of the presence of Cl^-, HCO_3^-, SO_4^{2-}, NO_3^- and natural organic matter (NOM). FCA beads were also used with actual lake waters (11-69 µg PO_4^{3-}-P/L) and 81-100% phosphate removal was observed in 24 h. The FCA beads having a point of zero charge (PZC) of 9.2 make it an ideal candidate for phosphate removal in eutrophic lakes. Phosphate-laden spent iron cross-linked alginate (FCA) beads were subsequently used in hydroponics to evaluate the bioavailability of P and Fe using lettuce (*Lactuca sativa*) as a test plant. Phosphate-laden spent FCA beads were found to support the plants throughout the growth period. The bioavailability of P and Fe in the spent beads is promising considering the importance of phosphorus and iron in global nutrient security.

Navaratnam Leelaruban: A Study of the Spatial and Temporal Characteristics of Drought and its Impact in North Dakota



This study focuses on two important aspects of drought: variability of drought characteristics across different spatial scales, and impact of droughts on crop yield and groundwater. Two drought indices, one integrating severity and spatial coverage, and also taking into account the type of specific crops, were investigated for county level use. The developed indices were used in studying drought at the county level, and its impact on crop yields in North Dakota. These indices can be used for resource allocation at the county level for drought management. Drought is reported in the United States for different administrative units at different spatial scales. The spatiotemporal variation of drought characteristics across different spatial scales and scale dependence was investigated, demonstrating the importance of considering spatial scales in drought management. A methodology is proposed to quantify the uncertainty in reported values of drought indices using geostatistical tools, and station-based Standardized Precipitation Index (SPI) from North Dakota. The uncertainty was found to increase with increasing spatial scale size. The impact of drought on groundwater resources was modeled using linear regression. Of the several drought indices, SPI-24 was found to correlate the best with groundwater levels. In addition, the duration of drought also had significant correlation with groundwater level declines. This study also investigated the effect of different drought conditions on Barley yield using Multiple Linear Regression (MLR) and Artificial Neural Network (ANN) methods. The ANN model performs better than MLR in estimating barley yield. ANN is proposed as a viable alternative method or in combination with MLR to investigate the impact of droughts on crop yields.

2015 — 2016 NDWRRI Fellowship Research Highlights

Anthony Wamono: Effects of Calcium Based Surface Amendments on the Hydraulic Conductivity and Selected Physical Properties of Subsurface Drained Sodic-Saline Soils

"Northern U.S. Great Plains' saline/sodic soils often have very low yields due to poor germination, become exceptionally hard when the soil dries, and can be a sediment source following rainfall events. In addition, subsurface drainage can result in the conversion of saline/sodic soils to sodic soils. Calcium-based surface amendments (Ca-amendments) may help preserve or improve soil structure, thereby improving drainage and trafficability. The objective of this study to determine the impact of selected subsurface drainage practices and Ca-amendments on tillage power requirements. The research was conducted in a sodic soil near Wyndmere North Dakota, the experiment used a completely random design with a split-plot arrangement in which whole plots consisted of free-outflow subsurface drainage (FD) and no subsurface drainage (ND); split plots consisted of Ca-amendments of 11.2 and 22.4 Mg ha^{-1} gypsum (GL and GH), 22.4 Mg ha^{-1} spent lime (SL), and check (CK) with no Ca-amendments. A drawbar dynamometer measured draft on a chisel plow that was pulled across the plots by a tractor equipped with an auto-guidance system and instrumentation interfaced its controller area network. No significant differences were observed in the mean drawbar power (P_d) of drainage treatments, 53.6 kW for FD and 53.4 kW for ND. Compared with CK (54.8 kW), gypsum lowered the mean P_d (50.4 kW for GH and 51.2 kW for GL) while SL increased the mean P_d (57.6 kW). The P_d for GL was similar to that of GH. For the combined effects of drainage and surface treatments, the P_d of NDGH (48.9 kW) was significantly lower than (51.7, 51.8, and 53.1 kW) of FDGL, FDGH, and FDCK, respectively, which shows that drainage may have reduced soil moisture Ca activity. Twenty-three months after subsurface drainage installation, P_d was lower (53.1 kW) in FDCK than NDCK (56.4 kW). These findings suggest that subsurface drainage lowered drawbar power compared to no subsurface drainage when no amendments were applied. For low productivity soils, NDGH had the lowest P_d, which may be a less costly approach to reducing drawbar power requirements compared with drainage coupled with gypsum application." [Copyright 2016 ASABE, used with permission. Abstract from Wamono, A., D.D. Steele, Z. Lin, T. DeSutter, X. Jia, and D. Clay. 2016. Gypsum lowers drawbar power in Northern Great Plains subsurface drained sodic soils. *Trans. ASABE* (Manuscript ID NRES-11689-2015; accepted 26 Sept 2016).]

Jingyi Sun: Bioavailablity of Dissolved Organic Nitrogen to Algal Species

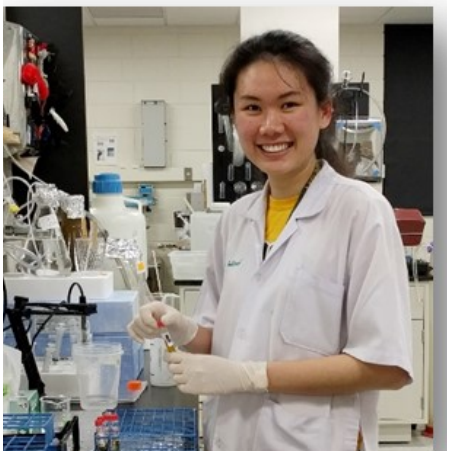
Due to the increased concern on dissolved organic nitrogen (DON) in surface waters, it is important to understand the biodegradability and bioavailability of DON in point and non-point sources. In this study, algae and bacteria were applied under lab condition to understand the impact of DON on water environment. Biodegradable DON (BDON) was determined using bacteria while bioavailable DON (ABDON) was determined using green algae *Selenastrum capricornutum*, *Chlamydomonas reinhardtii,* and *Chlorella vulgaris* and/or mixed culture bacteria in municipal and animal wastewaters. Results showed that, the ranges of BDON and ABDON in municipal wastewaters were 50-60% and 30-77%, respectively, while the ranges of BDON and ABDON in animal wastewaters were 48-54% and 40-81%, respectively. In addition, *Chlamydomonas reinhardtii* and *Chlorella vulgaris* were utilized in this study in order to compare with the commonly used test species, *Selenastrum capricornutum*. In both wastewater sources, ABDON perentages for all three algae were not significantly different indicating that *Chlamydomonas reinhardtii* and *Chlorella vulgaris* can be used as a test species for nitrogen determination similar to *Selenastrum capricornutum*. This research provides important outcomes to improve the quality of receiving waters (Red River in North Dakota) by minimizing the nutrient entrance to surface waters either from wastewater treatment plants or from animal feedlots.

2015 — 2016 NDWRRI Fellowship Research Highlights

Mitchell Swanson: The Role of Algal Species on Phosphorus Bioavailability in Secondary Wastewater Effluents

Phosphorus (P) is a limiting nutrient responsible for the eutrophication of surface waters and marine coasts. Wastewater treatment technologies are being stressed to achieve low P effluents and national effluent P limits are expected in the coming years. This research investigates how different algae, as individual species and a mixed culture, utilize bioavailable phosphorus (BAP) when examined by the standard algal species *Raphidocelis subcapitata* along with *Chlorella vulgaris* and *Chlamydomonas reinhardtii* as additional test species. It also investigates how different P-species contribute to BAP using the standard algal species. Results show there is no significant difference in %(BAP/total dissolved P) among the cultures studied. But it is recommended that *R. subcapitata* remains the standard species as it provides the highest BAP concentration and would therefore provide the most conservative value for monitoring and regulative purposes. While % (BAP/total dissolved P or TDP) over the incubation period is not significantly different, the amount of P needed per gram of algal biomass for each species differs, as suggested by the growth curves and the normalized BAP ratio. This may affect eutrophication and the size of the floating algal-mats in water bodies depending on the dominant algal species and P levels that are present. The normalized BAP ratio may be used to predict the amount of green algae that would be produced from secondary effluent with a known BAP concentration and in turn potential contribution to eutrophication in receiving water bodies by the effluent. Results also show that all P-species contributed to BAP. The bioavailability of each P-species is approximately 95% and 75% for soluble reactive P (SRP) and soluble acid hydrolysable P for the samples from the Fargo and Moorhead wastewater treatment plants (WWTPs). Bioavailability of dissolved organic P (DOP) was 33% and 0% for the Fargo and Moorhead WWTP samples, respectively. The accuracy of the bioavailability of DOP is more difficult to determine as DOP is released by algae during the incubation period, thereby underestimating its true bioavailability. Additionally, an AONVA test indicates that no relation could be made between the P-species and BAP concertation. While a relation between P-species and BAP could not be made, it is still possible to use SRP as the low estimate of BAP in effluents and TDP or total P as the maximum estimate of BAP. This allows for a faster and more cost effective method of estimating BAP in effluents compared to bioassays that have long incubation periods and are more costly.

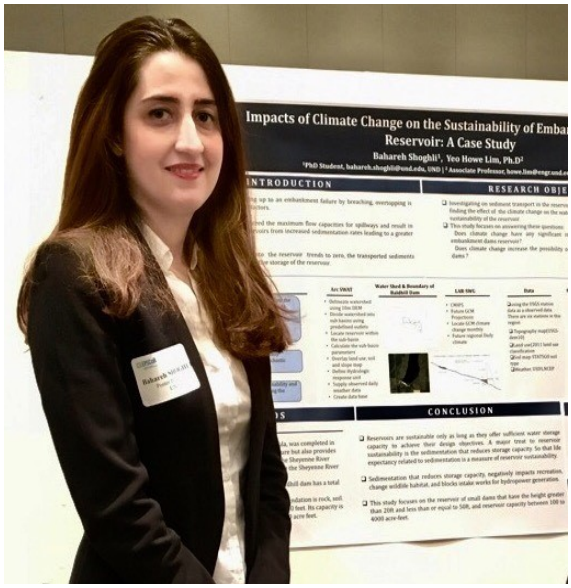
Boonsiri Dandumrongsin: Contribution of Soluble Microbial Products on Dissolved Organic Nitrogen and its Biodegradability in Wastewater Effluent



Global human population growth threatens the access to clear water resources and increases the intensive use of water for agriculture and urbanization. In order to maintain water sustainability in the future, it is challenging to lower the pollution levels of wastewater to meet the safe discharge quality standards. Other than the trace hazardous material in wastewater that poses the important risk to human health, nutrients are considered to be another potential contaminant, which can cause eutrophication and oxygen depletion. Specifically, nutrients in organic form can be used as a secondary source for bacterial uptake. This research is focused on understanding organic matter and its source from treated wastewater, especially nitrogen species. Along with the wastewater samples collected from two WWTPs, synthetic wastewater was also prepared to measure and compare protein and carbohydrate concentrations. Protein is found as a dominant substance while carbohydrate was a secondary element in the samples. Results showed that protein is released as a soluble microbial product during the biological process and was used as nitrogen source for the bacteria. However, the final protein concentrations in treatment plants are reduced over the treatment process, 50-80% of the initial protein was reduced during the biological treatment.

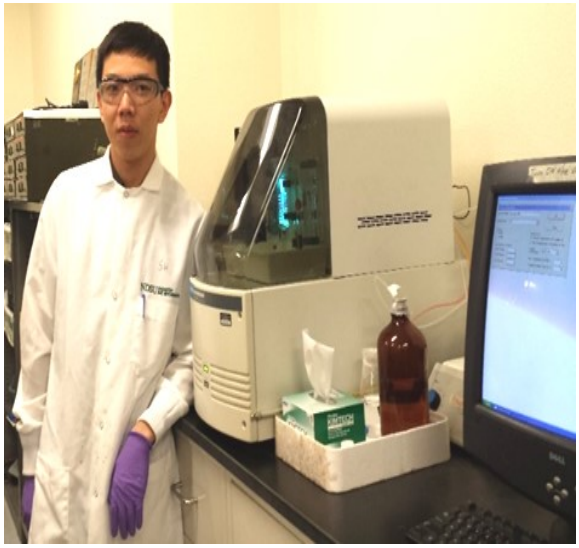
2015 — 2016 NDWRRI Fellowship Research Highlights

Bahareh Shoghli: Impacts of Climate Change on Embankment Dams in the Upper Midwest Region: Critical Design Parameters and Adaptation Measures



The objective of this research is to develop a framework for the evaluations of the impacts of climate change on the embankment dams and propose any adaptation measures to be reflected in design parameters. Case studies on near-failure in the regions in recent years will be scrutinized for the purpose of developing a regression on flood risk with potential climate change parameters. Two critical variables of reservoirs that are potentially influenced by climate change are water elevation and sediment accumulation. By knowing the underlying parameters that influence these variables through model calibrations and simulations, we will be able to determine the behavior of reservoirs in future climatic conditions. For evaluating these underlying parameters, watershed of the study area will be simulated by ArcSWAT. Calibration and validation of this simulation are performed by SWAT-CUP (calibration period (1985-1999), validation period (2000-2014)). Calibrated model will be used for simulating sediment entrance to the reservoir. After finding the sediment entrance to the reservoir, the sediment accumulation will be estimated by trap efficiency formulas and a number of statistical analysis will be performed to determine the reservoir's capacity to within 95% confidence limit. The impacts of climate change on the hydrology of the region will be assessed based on the simulation of two periods (2020s and 2050s), using downscaled GCM projections. We will use an ensemble of projection from 15 CMIP5 GCMs and run that. The evaluated reservoir characteristics and parameters will be applied to the simulating periods in the 2020s and 2050s. Understanding the sediment dynamics and identifying the main effective parameters on erosion of soil will help to optimize the strategies for minimizing sediments entrance which are the main source of methane production. When methane combines with oxygen, it will produce CO2, and both have the greatest contribution to greenhouses gases.

Soklida Hong: Glutaraldehyde Removal from Flowback and Produced Waters Using Photolysis



In unconventional oil and gas extraction, hydraulic fracturing has been applied to induce cracking network in low-permeability shale to allow trapped oil and/or gas flow to the production wells. It requires injection of fluid at extremely high pressure and flow rate. Most of the injected fluid along with formation water, collectively known as produced waters, return to the surface just after the hydraulic fracturing process and throughout the entire life-span of production well. Hydraulic fracturing fluid is mainly water (98-99%) and proppant (mostly sand, 1-1.9%); however, several chemicals, including biocides, are added to the water to increase hydraulic fracturing performance. After hydraulic fracturing, biocides are also periodically injected to the wellbores to prevent microbial growth that causes corrosion to the infrastructure. Glutaraldehyde (GA) is the most common biocide accounting for 80% of all shale fracturing in the United States. It is a harmful chemical to environment, humans and aquatic organisms. GA also inhibits microbial activity in produced waters making bioremediation a non-viable option. In this study, photolysis was used to remove GA from brine simulating produced waters since the technology has small footprint and is easy to operate and effective against organic compounds. About 80% of 10 mg/L of GA was removed in brine solution with NaCl concentration at 200 g/L and pH at 7, such a condition similar to that of actual produced waters, after 1 h irradiation under 254 nm UV. The results also indicated that GA removal increased with increasing in NaCl concentration. This study helps in addressing an obstacle associated with produced water treatment, disposal as well as reuse.

2015 — 2016 NDWRRI Fellowship Research Highlights

Ryan David: Impacts of Mixing and Pumping Control on Water Tower Water Quality

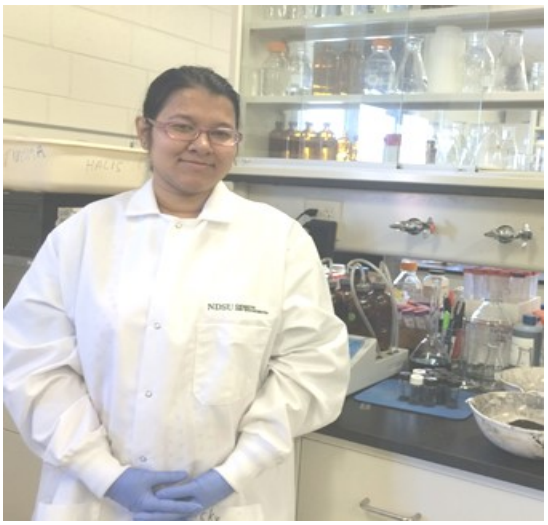
Water towers are used in water distribution systems to equalize pumping rate, to maintain stable system pressure, and to provide storage for fire protection. However, water towers are often not designed or operated to maintain water quality, and may experience water quality degradation if not properly managed. Poor water tower mixing can cause disinfectant loss, nitrification, bacterial regrowth and disinfection by-products formation. Thermal stratification in summer months can further aggravate these water quality problems. The purpose of this study is to investigate water quality variations in three Moorhead, MN, water towers with or without mixing. Results of this study confirmed that without mixing thermal stratification occurred and led to water quality degradation in summer months. Thermal stratification was effectively eliminated by operation of the mixers installed in water towers. However, water quality in these towers was not improved. A new method to determine the hydraulic residence time was developed and it was discovered that long hydraulic residence time was likely the cause of significant chlorine depletion and water quality deterioration. To prove this hypothesis and to maintain good water quality in the Moorhead water distribution system, a new water tower operation procedure was implemented to reduce summer month hydraulic detention time. Results from the second year of this study showed that the modified pumping control along with mixing greatly improved the water quality in the water towers.

Swati Sharma: Removal of Wastewater Derived Dissolved Organic Nitrogen Using Bacteria-Algae Consortia and UV Light Irradiation

Dissolved Organic Nitrogen (DON) has a complex structure and it is not readily available to some species in aquatic ecosystems. A method needed to discover to degrade DON to low molecular weight compounds, and ultimately make it readily available to some species including algae, bacteria, micrograzers, bacterioplankton, cyanobacterium, and phytoplankton. Understanding the biodegradability, bioavailability and photodegradability characterisitics of wastewater derived DON is important in achieving successful removal of DON using algae, bacteria and UV light irradiation. Biodegradable DON (BDON) is mineralized by bacteria while bioavailable DON (ABDON) is utilized by algae + bacteria. Photodegradable DON (PDON) is a portion of DON that is decomposable by sunlight or artificial light to lower molecular weight compounds. This study evaluates the fate of DON when introduced to a series of systems integrated with moving bed biofilm reactor (MBBR) media, UV light irradiation, bacteria and algae+bacteria incubation. The system was operated at 3 different hydraulic retention times (HRT) of 1, 3 and 6 days. Further, the effluent samples from each reactor and UV light exposure were incubated for 21 days seeding with bacteria and algae+bacteria. The optimum removal of organic nitrogen was achieved at an HRT of 3 days. Throughout all three HRTs, the lowest concentration of BDON and PDON were 1.86 (about 60-70% DON reduction) and 0.50 mg/L (about 40-50% DON reduction), respectively while the ABDON concentration fluctuated about 40-70%. Lower HRT of 1 day in MBBR reactor resulted in inefficient removal of nutrients whereas 6 days of HRT resulted in low nutrient uptake and cell lysis. From the alage+bacteria seeded samples, it could be understood that DON in receiving waters could be utilized by algae in the presence of bacteria. Thus, working towards reduction of DON should be considered a primary concern in the treatment plants before it discharges to the receiving water bodies.

2015 — 2016 NDWRRI Fellowship Research Highlights

Umma Rashid: Removal of Trichloroethylene and Fluoride from Water by Nanoscale Zero-Valent Iron Supported on a Novel Activated Carbon



Trichloroethylene (TCE) has been found in at least 60% or 861 of the NPL (National Priorities List or Superfund) sites and there are tens of thousands of other cleanup sites across the country (USEPA, 2011). Due to industries, landfills and factories, the groundwater in Valley City, North Dakota has been found adversely affected by TCE contamination (USEPA, 2010). Sheyenne River at Valley City has TCE levels beyond the acceptable limits (5µg/L) as prescribed by USEPA. A huge contaminated site was found in West Fargo, ND. The leak from a dry cleaning facility caused this contamination. In addition, there are concerns about fluoride in North Dakota as well. Eight counties have fluoride level more than 4 mg/L and fifteen counties have fluoride level higher than 1.5 mg/L. Nanoscale zero-valent iron (NZVI) is an effective reducing agent for removing trichloroethylene (TCE) and an effective adsorption material for fluoride removal from groundwater. However, bare NZVI agglomerates, settles down very quickly and lose their reactivity in aqueous environment. A wood based activated carbon (AC) was prepared by chemical activation with different metal salt to get higher surface area, pore volume and organized pore structure on the surface of AC. To check and compare the quality of ACs, methylene blue removal study was done at two different initial concentrations. At lower concentration all the AC samples showed same amount of removal but at high concentration potassium salt showed better removal than sodium salt. NZVI will be supported on the surface of AC by mixing prepared activating carbon with ferrous sulfate heptahydrate followed by chemical reduction with $NaBH_4$. Different characterization technique will be done to get surface properties of prepared NZVI supported on AC (NZVI-AC). Batch studies will be used to evaluate the TCE and fluoride removal efficiency of NZVI-AC. In addition, the effect of initial TCE and fluoride concentration and pH will be investigated by doing batch experiments. Adsorption isotherm study will be conducted to determine the equilibrium adsorption capacity and mechanism of adsorption of fluoride on NZVI-AC

Luisa Torres: Holistic Risk Assessment of Surface Water Contamination by Naturally Occurring Radioactive Material in Oil Produced Water from the Bakken Shale

The risks to the environment and human health due to hydraulic fracturing (HF) in onshore unconventional oil and gas (O&G) development have been studied in the past but results are inconclusive. A common shortcoming in previous studies is the absence of social risk perception and awareness analysis. This research proposes the combination of statistical methods to analyze risks to human health due to improper management of produced water, the major by-product of HF. This study analyzes existing data from different states with unconventional O&G resources but the main focus is on the Bakken Shale and environmental conditions from North Dakota. Despite being the second largest producer of unconventional oil in the country, produced water data and risks assessments in ND are very scarce. This is particularly true for data on naturally occurring radioactive material (NORM). First, a risk assessment of radium-226, the most predominant radionuclide in NORM, was performed from a technical perspective only. A simulation model was used to determine the amount of Ra-226 that could accumulate in three food stuff and thus, reach ND residents. Second, a risk assessment, focused on lead-210 a decay product of Ra-226, was conducted by combining technical analysis with risk perception and awareness of ND residents. Results from both analyses indicate that the risks to human health due to NORM in produced water are not negligible and further analysis is recommended. The methods proposed in this study could serve as reference for future research. Results obtained with holistic risk assessments could greatly contribute to the mitigation of risks in O&G development by the creation and implementation of standards and regulations that consider both social and technical aspects.

Meet Our Faculty

Dr. Feng (Frank) Xiao is an Assistant Professor in the Department of Civil Engineering at the University of North Dakota (UND). He completed his Bachelor's (2003) and Master's (2006) degrees from Harbin Institute of Technology in China. He then worked at Hong Kong University of Science & Technology as a full-time research fellow from 2006 to 2009. He came to the US in August 2009 and received his Ph.D. degree in August 2012 from the University of Minnesota with a major in Civil Engineering (Environmental) and a minor in Environmental Health Sciences. Before joining UND in August 2015, he did his post-doctoral studies with Dr. John Gulliver at the St. Anthony Falls Laboratory and then with Dr. Joseph Pignatello at the Connecticut Agricultural Experiment Station.

Dr. Xiao's research interests span a range of topics on the food–water–energy nexus, including conventional and enhanced drinking-water treatment, emerging contaminants (detection, transport, fate and exposure), porous carbonaceous materials, agricultural biomass utilization, stormwater management, and treatment of hydraulic fracturing produced water. He is the author of 22 peer-reviewed publications (total citations of 543; H-index = 14) and a reviewer of 30+ referred journals and 110+ manuscripts, and currently serves on the Editorial Board of Environmental Pollution (Impact Factor = 4.84). His research group at UND that included only two undergraduate students in fall 2015 has already grown to seven members, including one postdoc associate, four graduate students, and two undergraduate students. He teaches three (2016) or five (2017) courses per year at UND, and consistently receives outstanding student evaluations (4.5–4.7 out of 5; with 5 being the highest).

Dr. Halis Simsek is an Assistant Professor at the department of Agricultural & Biosystems Engineering, North Dakota State University. He earned his B.S. degree in Environmental Engineering at Selcuk University and M.S. degree in Environmental Engineering at Gebze Technical University in Turkey. Later he moved to the United States and obtained another M.S. degree in Agricultural & Biological Engineering at Purdue University. He obtained his Ph.D. degree in Civil Engineering at North Dakota State University in December, 2012.

Dr. Simsek's research interests mainly pertain to water and wastewater treatment, water quality, agricultural structures and livestock housing environment, and agricultural waste management. Specific interests include; a) Fate and transport of nutrients in the agricultural systems and in water resource recovery facilities, b) mathematical/numerical modeling of agricultural and environmental systems, c) evaluation of impacts of agricultural production on surface and groundwater quality, d) algal blooms in surface waters, e) biological wastewater treatment, environmental biochemistry, microbial processes for bioremediation of organic and inorganic substances, and f) photochemical and electrochemical application on water and wastewater treatment. Dr. Simsek teaches Bioenvironmental System Design and Management of Agricultural Systems (Capstone) courses in the department.

Dr. Jon Sweetman is an Assistant Professor in Biological Sciences at North Dakota State University, where his research is focused on understanding the cumulative impacts on freshwater ecosystems from changes in climate, land use and other environmental factors. Jon's research uses several approaches, including large-scale surveys, experimental approaches, including mesocosms, and paleolimnology, examining past changes archive in lake sediments. He completed his undergraduate in Biology at the University of Regina, Saskatchewan, Canada, a M.S. in Biological Oceanography at the University of Alaska Fairbanks, and his Ph.D. at Queen's University in Kingston, Ontario, Canada. Prior to joining NDSU, Jon worked in both provincial and federal governments in Canada: as the manager of Water Resources for Alberta Innovates – Energy and Environmental Solutions, and as an aquatic ecologist for Parks Canada.

NDSU Students Volunteer at WEFTEC

On September 24, 2016, over 100 Water Environment Federation Technology and Exposition Conference (WEFTEC) attendee volunteers helped at the 9th Annual WEF Community Service Project on the grounds of New Orleans City Hall, 1300 Perdido Street. NDSU students who volunteered for the community service project included Ruchi Joshi (past NDWRRI Fellow), Aundie Softing, Eric Miller, Josh Hammermeister, Jamal Ghauri and Matthew Lee.

The annual WEF community service project was organized by the Water Environment Federation (WEF) Students and Young Professionals Committee (SYPC). The project served as an educational platform for the community to learn about water, environment, and green infrastructure. The community service project this year was named "NOLA Grows Green: The City Hall Stormwater Project" and for the first time, members of the WEF House of Delegates also participated in the service project. This year's project will help capture stormwater that is overflowing from a parking garage and onto the sidewalk and street at City Hall. To mitigate the flooding, volunteers constructed 2 bioswales to slow and filter stormwater runoff from the parking garage and building roof. The volunteers were responsible for backfilling a 1,210 square foot bioswale, excavating and backfilling a 180 square foot rain garden, followed by planting both areas, and installing 5 Black Gum trees. The green infrastructure will capture over 2,300 cubic feet of runoff. Transportation, lunch, and a project t-shirt was provided to the participants

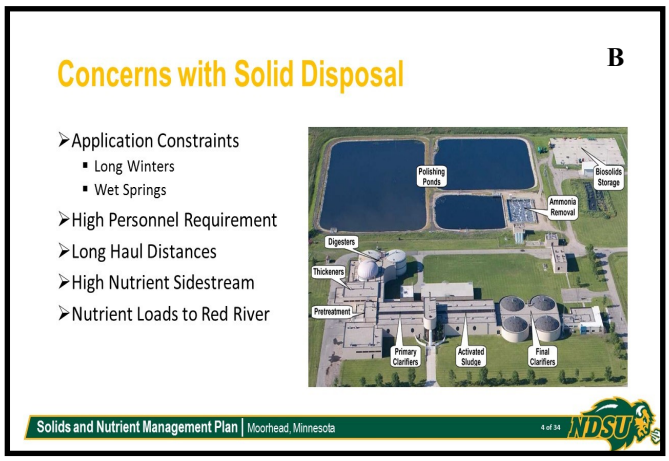
This years' service project was conducted in partnership with the Dana Brown & Associates, the City of New Orleans, the Sewerage and Water Board of New Orleans. The Community Service Project will continue to promote grassroots solutions and environmental stewardship on a local level by implementing green infrastructure and sustainable projects to improve water quality in the community. The sponsors were AECOM, ARCADIS U.S. Inc., Black & Veatch, Brown and Caldwell, Carollo Engineers, CDM Smith, CH2M, Evoqua Water Technologies, Greeley and Hansen, Hazen and Sawyer, HDR Engineering, WSP Parsons Brinkerhoff, and NYC Department of Environmental Protection. The service project event in action can be accessed at *YouTube link:* "https://www.youtube.com/watch?v=cjmRHjxcUIc"

Before (Left) and after (Right) WEF Community Service Project at the City Hall of New Orleans, LA.
Photo courtesy: Antrup, New Orleans City Planning Commission and WEF.

Members of the WEF House of Delegates participated in the service project for the first time (Left)
NDSU student group volunteers at the WEF community service project (Right) .

NDSU WEFTEC Design Team

NDSU Wins 4th Place in Environmental Design Competition at WEFTEC 2016



The North Dakota State University team placed fourth in the student design competition's wastewater design category. A) WEF President-Elect; Jenny Hartfelder with NDSU student team (Aundie Softing, Eric Miller and Matthew Lee) and faculty advisor, Wei Lin (ND WRRI Faculty). Photo courtesy WEF. B) A glimpse of the issues used to justify the project titled 'Biosolids and Nutrient Management at Moorhead Wastewater Treatment Facility (MWWTF), Moorhead, MN'.

North Dakota State University (NDSU) competed in the Environmental Design Competition at the 89th Annual Water Environment Federation Technical Exhibition and Conference (WEFTEC) in New Orleans, LA. The 15th annual competition was held on September 25th, 2016 and is open to all universities nationwide. WEFTEC student design competition hosts competitions in following 2 categories: Wastewater Design (e.g. hydraulics, capacity design, and upgrades to existing systems) and Environmental Design (e.g. contemporary engineering topics such as sustainability and water reuse).

The NDSU student chapter team, who represented the North Dakota Water Environment Association, competed in wastewater design category and won the fourth place out of the 8 teams in that category. The team included Civil and Environmental Engineering senior students: Eric Miller, Aundie Softing, Brian Rucker, Charlie Bowen, Matthew Lee, Carl Entzie and Oluyemi Abodunrin. The team that presented the final project during the WEFTEC included Eric Miller, Aundie Softing and Matthew Lee. The project, 'Biosolids and Nutrient Management at Moorhead Wastewater Treatment Facility (MWWTF), Moorhead, MN', presented by the NDSU team was developed as a part of the Environmental Engineering Design (CE 499/696) class coordinated by Dr. Wei Lin (ND WRRI Faculty) in Spring 2016. The project focused on reducing the biosolids volume through dewatering and side stream management of nutrients from additional filtrate generation at the MWWTF.

The competing teams submit a design report for review by the judges in advance. During the conference, the teams give an oral presentation of their design project followed by a Q & A session with the judges. The project presented by NDSU team was well received by a panel of judges comprising of professional engineers and consultants. The team was awarded fourth place in the competition along with certificates, and a monetary award of $750. The conference also provided opportunities for professional networking through career fairs, a great learning experience through an open exhibition hall, technical sessions and much more.

Recent Publications and Presentations by Institute Fellows and PIs

Journal Papers

Dose, H. L., A. M. Fortuna, L. J. Cihacek, J. Norland, T. M. DeSutter, D. E. Clay, J. Bell (2015) Biological indicators provide short term soil health assessment during sodic soil reclamation. Ecological Indicators, 58, 244-253.

Habtezion, N., M. T. Nasab, X. Chu (2016) How does DEM resolution affect microtopographic characteristics, hydrologic connectivity, and modelling of hydrologic processes? Hydrological Processes, 30.25, 4870-4892.

Simsek, H., M. Kasi, J.-B. Ohm, S. Murthy, E. Khan (2016) Impact of solids retention time on dissolved organic nitrogen and its biodegradability in treated wastewater. Water Research, 92, 44-51.

Torres, L., O. Yadav, E. Khan (2016) A review on risk assessment techniques for hydraulic fracturing water and produced water management implemented in onshore unconventional oil and gas production. Science of the Total Environment, 539, 478-493.

Wamono, A., D.D. Steele, Z. Lin, T. DeSutter, X. Jia, D. Clay (2016). Effects of calcium based surface amendments on the penetration resistance of subsurface drained sodic soils. Transactions of the ASABE, 59(4), 869-877.

Conference Proceedings

Hong, S., T. Ratpukdi, J. Sivaguru, E. Khan (2016) Glutaraldehyde removal from flowback and produced waters using photolysis, in Proceeding 89th Annual Water Environment Federation Technical Exposition and Conference, Water Environment Federation, Alexandria, VA.

Lim, S. H., Z. Lin, M. Borders, T. Lin (2016) Shale oil production expansion and water-energy nexus in North Dakota: a decentralized agent-based modeling approach, in Agricultural and Applied Economics Association Annual Meeting, Boston, MA.

Lim, Y. H., A. M. Beaudry, N. Lindstrom, R. Hanson (2016) Efficiency assessments of a city's BMP in a cold region, in World Environmental and Water Resources Congress, 319-328.

Sharma, S., D. L. Tucker, H. Simsek (2016) Wastewater derived dissolved organic nitrogen removal using integrated system of biological reactors and UV light irradiation, in Proceeding 89th Annual Water Environment Federation Technical Exposition and Conference, Water Environment Federation, Alexandria, VA.

Shoghli, B., Y. H. Lim, J. Alikhani (2016) Evaluating the effect of climate change on the design parameters of embankment dams: case studies using remote sensing data, in World Environmental and Water Resources Congress, 575-585.

Swanson, M., M. Kasi, E. Khan (2016) Bioavailability of phosphorus species in secondary effluents, in Proceeding 89th Annual Water Environment Federation Technical Exposition and Conference, Water Environment Federation, Alexandria, VA.

Conference/Seminar Presentations

Hong, S., T. Ratpukdi, J. Sivaguru, E. Khan (2016). Glutaraldehyde removal from flowback and produced waters using photolysis. The 89th Annual Water Environment Federation Technical Exposition and Conference, Water Environment Federation, September 24-28, 2016, New Orleans, LA.

Lim, S. H., Z. Lin, M. Borders, T. Lin (2016). Shale oil production expansion and water-energy nexus in North Dakota: a decentralized agent-based modeling approach. Agricultural and Applied Economics Association Annual Meeting, July 31- August 2, 2016, Boston, MA.

Lim, Y. H., A. M. Beaudry, N. Lindstrom, R. Hanson (2016). Efficiency assessments of a city's BMP in a cold region. World Environmental and Water Resources Congress, May 22-26, 2016, West Palm Beach, FL.

Martin, M., J. McEvoy, E. Khan (2016). Isolation and identification of microbes responsible for biodegradation of endoxifen in wastewater under aerobic batch condition. The 2016 North Dakota Water Quality Monitoring Conference, ND Water Quality Monitoring Council, March 2-4, 2016, Bismarck, ND.

Recent Publications and Presentations by Institute Fellows and PIs

Sharma, S., D. L. Tucker, H. Simsek (2016). Wastewater derived dissolved organic nitrogen removal using integrated system of biological reactors and UV light irradiation. The 89th Annual Water Environment Federation Technical Exposition and Conference, Water Environment Federation, September 24-28, 2016, New Orleans, LA.

Shoghli, B., Y. H. Lim, J. Alikhani (2016). Evaluating the effect of climate change on the design parameters of embankment dams: case studies using remote sensing data. World Environmental and Water Resources Congress, May 22-26, 2016, West Palm Beach, FL.

Steinman, A., C. Hargiss (2016). Understanding the impacts of urbanization on wetlands. The 2016 North Dakota Water Quality Monitoring Conference, ND Water Quality Monitoring Council, March 2-4, 2016, Bismarck, ND.

Swanson, M., M. Kasi, E. Khan (2016). Bioavailability of phosphorus species in secondary effluents. The 89th Annual Water Environment Federation Technical Exposition and Conference, Water Environment Federation, September 24-28, 2016, New Orleans, LA.

Torres, L., O. Yadav, E. Khan (2016). Holistic risk assessment of surface water contamination due to radioactivity in produced water from unconventional oil production in North Dakota. The 2016 North Dakota Water Quality Monitoring Conference, ND Water Quality Monitoring Council, March 2-4, 2016, Bismarck, ND.

Institute Publications

Technical Report No: ND16-01
The Cycling and Fate of Phosphorus at an Abandoned Feedlot
Prosper Gbolo and Philip J. Gerla

Technical Report No: ND16-02
Bioavailablity of Dissolved Organic Nitrogen to Algal Species
Jingyi Sun and Halis Simsek

Institute publications can be accessed via the Institute website: http://www.ndsu.edu/wrri

Theses and Dissertations

Dose, Heather Lynn (2016) Advancing soil health: Linking belowground microbial processes to aboveground land management. Ph.D. Dissertation, Department of Soil Science, College of Agriculture, Food Systems, and Natural Resources, North Dakota State University, Fargo, ND.

Hossain, Mohammad Enayet (2016) Iron nanoparticles and biopolymers for plant nutrient fortification. Ph.D. Dissertation, Environmental and Conservation Sciences Program, College of Graduate and Interdisciplinary Studies, North Dakota State University, Fargo, ND.

Leelaruban, Navaratnam (2016) Spatial scale dependence of drought characteristics and impact of drought on agriculture and groundwater. Ph.D. Dissertation, Department of Civil and Environmental Engineering, College of Engineering, North Dakota State University, Fargo, ND.

Valkov, Veselina Aleksandrova (2016) Impact of artificial aeration on phytoplankton growth and seasonal succession in a Eutrophic Lake. Ph.D. Dissertation, Environmental and Conservation Sciences Program, College of Graduate and Interdisciplinary Studies, North Dakota State University, Fargo, ND.

Silvis, Brent (2016) An Assessment of the influence of economic drivers of land use change on nitrate concentrations in the Red River of the North Basin. M.S. Thesis, Department of Earth System Science and Policy, John D. Odegard School of Aerospace Sciences, University of North Dakota, Grand Forks, ND.

Theses and Dissertations

Swanson, Mitchell (2016) The role of algal species on phosphorus bioavailability in secondary wastewater effluents. M.S. Thesis, Department of Civil and Environmental Engineering, College of Engineering, North Dakota State University, Fargo, ND.

Torres Gramajo, Luisa Fernanda (2016) Holistic risk assessment of surface water contamination by naturally occurring radioactive material in oil produced water from the Bakken Shale. M.S. Thesis, Department of Civil and Environmental Engineering, College of Engineering, North Dakota State University, Fargo, ND.

Recent USGS Reports

Water-surface elevation and discharge measurement data for the Red River of the North and its tributaries near Fargo, North Dakota, water years 2014–15
William C. Damschen and Joel M. Galloway
2016, Scientific Investigations Report 2016–1139

http://dx.doi.org/10.3133/ofr20161139

Stochastic model for simulating Souris River Basin precipitation, evapotranspiration, and natural streamflow
Kelsey A. Kolars, Aldo V. Vecchia, and Karen R. Ryberg
2016, Scientific Investigations Report 2015–5185

http://dx.doi.org/10.3133/sir20155185

Regression equations to estimate seasonal flow duration, n-day high-flow frequency, and n-day low-flow frequency at sites in North Dakota using data through water year 2009
Tara Williams-Sether and Tara A. Gross
2016, Scientific Investigations Report 2015–5184

http://dx.doi.org/10.3133/sir20155184

Recent ND State Water Commission Publications

Facts about North Dakota Fracking and Water Use
ND State Water Commission
2016

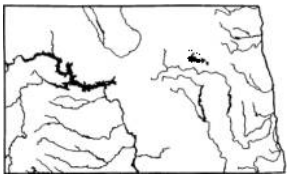
http://www.swc.nd.gov/pdfs/fracking_water_use.pdf

5th NDWRRI Annual Distinguished Water Seminar

The annual 5th Distinguished Water Seminar sponsored by the Institute was held on February 18, 2016. The featured speaker was Dr. Paul Westerhoff, Professor in the School of Sustainable Engineering and the Built Environment at Arizona State University. Dr. Westerhoff, is also the Senior Advisor to the ASU Provost on Science and Engineering. His presentation title was "Water Information Technology: Modeling DeFacto Wastewater Reuse Across the USA ." The seminar was co-sponsored by the Departments of Civil and Environmental Engineering, and Agricultural and Biosystems Engineering, the Environmental and Conservation Sciences Program, all of North Dakota State University. The seminar is the fifth of the annual Distinguished Water Seminar series by eminent water professionals on emerging issues, challenges and new research directions in water resources.

Abstract: The National Research Council 2011 report lists quantifying the extent of de facto (or unplanned) potable reuse in the U.S. as the top research need associated with assessing the potential for expanding the nation's water supply through reuse of municipal wastewater. Efforts to identify the significance and potential health impacts of de facto water reuse are impeded by outdated information regarding the contribution of municipal wastewater effluent to potable water supplies. De facto wastewater reuse occurs when treated wastewater is discharged in surface waters upstream of potable water treatment plants. Wastewater treatment plant (WWTP) discharges threaten water quality at the downstream drinking water treatment plant (DWTP). However, it is also a reliable water supply source! De facto reuse occurrence has been reported in regional studies, but a national assessment hadn't been completed in over 30 years. Overall, 50% of the DWTP intakes were potentially impacted by upstream treated WWTP discharges. Knowledge regarding the contribution of municipal wastewater to potable water supply, and efforts for identifying the significance and potential health impacts of de facto reuse are needed. Such research can contribute to the judicious use of "wastewater for drinking" in the US and across the globe.

Following the seminar, students and faculty had the opportunity to interact with Dr. Westerhoff.



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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.