North Dakota Water Resources Research Institute
Annual Technical Report
FY 2015

Introduction

This report describes the activities of the North Dakota Water Resources Research Institute (NDWRRI) during the period of March 1, 2015 to February 29, 2016.

The ND WRRI is one of the 54 institutes known collectively as the National Institutes for Water Resources. The NDWRRI was founded in 1965, by authority of Congress (Water Resources Research Acts of 1964, 1972, 1984, and 1990), and is administrated through the United States Geological Survey. Section 104 of the Water Resources Research Act requires the NDWRRI to apply its Federal allotment funds to:

1. Plan, conduct or otherwise arrange for competent 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 public. 2. Cooperate closely with other colleges and universities in the state that have demonstrated the capability for research, information dissemination and graduate training, in order to develop a statewide program designed to resolve State and regional water and related land problems. 3. Cooperate closely with other institutes and other organizations in the region to increase the effectiveness of the Institute and for the purpose of promoting regional cooperation.

This year (2015-2016), NDWRRI once again allocated its 104(B) resources to fund Graduate Fellowship research projects. The institute also continued its efforts to enhance communication between the State and Federal agency personnel and university faculty and students. NDWRRI also worked closely with the Environmental and Conservation Sciences program of North Dakota State University (NDSU) and Natural Resources Management program of NDSU on water related research issues and collaboration.

The annual base grant amount received by NDWRRI was $92,335. The amount was used for administration and Fellowship awards. The Fellowship program was supported by the North Dakota State Water Commission with an additional amount of $13,350.

Program Management

The Institute continued the same administrative mechanism with a new director managing the institute program with the help of a State Advisory Committee. Dr. Eakalak Khan, Professor of Civil and Environmental Engineering, replaced Dr. G. Padmanabhan, Professor of Civil and Environmental Engineering, as the director starting March 1, 2015. Linda Charlton-Gunderson, a NDSU employee, has been working part-time for the Institute to assist the director with Institute finances, communications and information transfer. The State Advisory Committee consists of three members representing the three principal water agencies in North Dakota: State Water Commission, State Department of Health, and the U.S. Geological Survey North Dakota District. In addition, the Institute also seeks advices from the faculty of the two research universities of the State: NDSU and University of North Dakota (UND).

State Appropriation

The North Dakota State Water Commission (NDSWC) continued its support of 15% match ($13,850) to the 2015-2016 Graduate Research Fellowship program of NDWRRI under federal 104(B) funding. This is twelfth year the NDSWC provided support to the Fellowship program.

University Support

North Dakota State University and the University of North Dakota administrations consider the NDWRRI activities important and are supportive of its efforts.

Institute Location

The Institute continues to operate from the Administrative Building of the College of Engineering of North Dakota State University in Fargo, North Dakota. The director may be reached at: ND Water Resources Research Institute, North Dakota State University, Civil and Environmental Engineering Dept. (# 2470), P.O. Box 6050, Fargo, ND 58108-6050, Phone: (701) 231-7717, Fax: (701) 231-6185, E-mail: eakalak.khan@ndsu.edu.

State Advisory Committee

The State Advisory Committee provided guidance on water resources research priorities in the State and region, and participated in the review and evaluation of research proposals and projects. The current committee members are:

1. Gregg Wiche, Former District Chief (Assigned by Current District Chief, Joel Galloway), U.S. Geological Survey, Water Resources Division, Bismarck, North Dakota 2. William Schuh, Water Appropriation Division, NDSWC, Bismarck North Dakota 3. Peter Wax, Water Quality Special Projects, North Dakota Department of Health, Bismarck, North Dakota

The committee members are senior officials in the three major agencies in North Dakota responsible for much of the water resources research done outside of NDSU and UND in North Dakota.

Research Program Introduction

Annual Base Grant (104-B)

In the past several years, NDWRRI has offered competitive fellowships to NDSU and UND graduate students for research on water resources topics under a Graduate Research Fellowship (GRF) program effectively using the modest amount of the 104(B) annual base grant. The program meets the requirements of Section 104 of the Water Resources Research Act of 1984.

The fellowship program encourages entry of young university faculty and new research scientists and engineers into the water resources field; provides training and education to future water resource scientists and engineers; promotes exploration of new ideas that address water problems or expand understanding of water quantity, quality and related phenomena; and engages university faculty in collaborative research programs seeking supports from entities concerned with water problems.

This year also, the NDWRRI continued the GRF program and applied bulk of the federal allotment to it. The GRF program is administrated and monitored by the director. Applications are invited from the graduate students and their advisors of the two research universities of the State, NDSU and UND. A rigorous review by the State Advisory Committee and other water professionals in the state determines the awards. Active participation of the academic advisors of the students in meeting matching requirement and seeking co-funding from local, state and other sources is another positive aspect of the program. Periodical review of the progress of the students in meeting the fellowship expectations is ensured by seeking reports from the students and by encouraging them to make presentations in local, regional, and national technical seminars and conferences.

Guidelines for the 2015-2016 Graduate Research Fellowship were posted on the Institute website in the first week of October 2014, and the request for applications was announced in the faculty news publications of the two university campuses by the second week of October, 2015.

The following is the request for application that was published on the UND and NDSU campus newsletters, and distributed by e-mail lists.

2015 ND WRRI graduate research fellowship applications invited

The North Dakota Water Resources Research Institute (ND WRRI) invites applications for its 2015 Graduate Research Fellowship program.

North Dakota State University and University of North Dakota graduate students who are conducting or planning research in water resources may apply for fellowships of varying duration, 3 months to one year. Typically in the past fellowship awards for master’s degree students have been in the range $800-$1,000 and for doctoral students it has been $1,000-$1,400 per month. The fellowship funds must be applied between March 1, 2015, and Feb. 29, 2016. A technical completion report co-authored by the fellow and the adviser is expected of each fellowship research project.

Research proposed for fellowship support should relate to water resources issues in the state or region. Regional, state or local collaborations or co-funding will strengthen an application. Fellowships have a matching requirement of two non-federal dollars to one federal dollar. At the time of applying, applicants should have a plan of study filed and/or should have a thesis research topic selected. Applications need to be prepared in consultation with advisers. Advisers of the applicant should co-sign the applications. Applications from students and advisers who have not met the reporting requirements of their previous fellowship projects

will not be considered for funding.

The general criteria used for proposal evaluation include scientific merit, originality, research related to state or region, and extent of regional, state or local collaboration and/or co-funding. The proposals will be reviewed by a panel of state water resources professionals.

Announcement of awards will be made by early January subject to the appropriation of funds for the FY 2015 program by the federal government.

Consult the ND WRRI Web site, www.ndsu.edu/wrri, for background information on the program, and guidelines for preparation of applications. Applications are due by Wednesday 5 p.m., November 26, 2014.

Submit original and four hard copies of applications to Linda Charlton, Family Life Center (FLC 320), NDSU Department 2030, P.O. Box 6050, Fargo, ND 58108-6050 and an electronic copy in Word format to G.Padmanabhan@ndsu.edu.

For additional information, contact Padmanabhan at G.Padmanabhan@ndsu.edu or Charlton at Linda.Charlton@ndsu.edu.

The above announcement appeared in NDSU News. An announcement similar in content was also published in the University of North Dakota campus publication University Letter.

NDWRRI Graduate Research Fellowships

In total, sixteen applications were received. Fourteen were from NDSU and two from UND. Out of sixteen, six (4 Ph.D. and 2 M.S.) are for renewal and ten (1 Ph.D. and 9 M.S.) are new applications.

Approximately $70,000 was available for Fellowship projects from the annual base grant. An additional support of $13,850 came from NDSWC. Fellowships ranging from $850 to $12,600 were awarded to sixteen graduate students, 5 Ph.D. and 11 M.S., conducting research in water resources topics at NDSU and UND. Selection of student Fellows and the award amounts were based on competitive proposals prepared by the students with the guidance of their advisers. A panel of state water resource professionals and the director reviewed the proposals and selected Fellows. The award amounts are based on the quality of proposals and the priority of the proposed projects for the state and region.

2015-16 ND WRRI Fellows, their advisers, and Fellowship research projects are:

1. Dandumrongsin, Boonsiri (Fellow), Environmental and Conservation Sciences Program, NDSU; Halis Simsek (Adviser); Contribution of Soluble Microbial Products on Dissolved Organic Nitrogen and its Biodegradability in Wastewater Effluent

2. David, Ryan (Fellow), Civil and Environmental Engineering Department, NDSU; Wei Lin (Adviser); Use of Mixers in Water Towers to Prevent Ice Formation and Improve Water Quality

3. DeGuise, Bryce (Fellow), Civil and Environmental Engineering Department, NDSU; Wei Lin (Adviser); Evaluation of Onsite Wastewater Treatment Systems – Sand Filters and Biological Treatment

4. Hong, Soklida (Fellow), Environmental and Conservation Sciences Program, NDSU; Eakalak Khan (Adviser) and Sivaguru Jayaraman (Co-adviser); Glutaraldehyde Removal from Flowback and Produced Water Using Photolysis

5. Hossain, Mohammad (Fellow), Environmental and Conservation Sciences Program, NDSU; Achintya Bezbaruah (Adviser); Biopolymers for Phosphate Removal from Eutrophic Lakes

6. Leelaruban, Navaratnam (Fellow), Civil and Environmental Engineering Department, NDSU; G. Padmanabhan (Adviser); A Study of the Spatial and Temporal Characteristics of Drought and its Impact in North Dakota

7. Rashid, Umma Salma (Fellow), Civil and Environmental Engineering Department, NDSU; Achintya Bezbaruah (Adviser); Injectable Nanoparticle-based Permeable Reactive Barriers for Groundwater Contaminant Remediation

8. Roy, Debjit (Fellow), Agricultural and Biosystems Engineering Department, NDSU; Xinhua Jia (Adviser); Snowmelt water infiltration into frozen soil in the Red River of the North Basin

9. Schewe, Rebecca (Fellow), Soil Science Department, NDSU; Francis Casey (Adviser) and Abbey Wick (Co-adviser); Quantifying Soluble Salt Removal from Subsurface Tile-Drain Agricultural Fields

10. Sharma, Swati (Fellow), Agricultural and Biosystems Engineering Department, NDSU; Halis Simsek (Adviser); UV Light Effect on Bioavailability of Dissolved Organic Nitrogen in a Trickling Filter Process

11. Shoghli, Bahareh (Fellow), Earth Systems and Policy, UND; Howe Lim (Adviser); Design Parameters of Embankment Dams in the Upper Midwest in Potential Climate Change Conditions

12. Silvis, Brent (Fellow), Earth Systems and Policy, UND; Haochi Zheng (Adviser); Analysis of the Impact of Policy and Economic Drivers of Land-Use Change on Nitrogen Levels of Surface Waters within the Snake, Buffalo and Eastern Wild Rice Subbasins, 2006-2013

13. Sun, Jingyi (Fellow), Agricultural and Biosystems Engineering Department, NDSU; Halis Simsek (Adviser); Evaluation of Bioavailable Dissolved Organic Nitrogen Using Various Algal Species

14. Swanson, Mitchell (Fellow), Civil and Environmental Engineering Department, NDSU; Eakalak Khan (Adviser); The Role of Algal Species on Phosphorus Bioavailability

15. Torres, Luisa (Fellow), Civil and Environmental Engineering Department, NDSU; Eakalak Khan (Adviser) and Om Yadav (Co-adviser); Risks of Water Contamination Associated with the Wastewater from Oil Production in the Bakken

16. Wamono, Anthony (Fellow), Agricultural and Biosystems Engineering Department, NDSU; Dean Steele (Adviser); Effects of Calcium Based Surface Amendments on the Hydraulic Conductivity and Selected Physical Properties of Subsurface Drained Sodic-Saline Soils

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

Basic Information

Title:	Contribution of Soluble Microbial Products on Dissolved Organic Nitrogen and its Biodegradability in Wastewater Effluent
Project Number:	2015ND293B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Wastewater, Nutrients, Treatment
Descriptors:	None
Principal Investigators:	Halis Simsek

Publication

1. Dandumrongsin, B., H. Simsek, 2015, A Method to Determine Biodegradability of Organic Nitrogen Using Laboratory Scale Column System. North Dakota Experimental Program to Stimulate Competitive Research (ND EPSCoR) State Conference, April 22, 2015, Fargo, ND. (Poster)

Research Description

According to intensive growing in water demand, lowering wastewater pollution level is very important and challenging in order to achieve water security toward a sustainable way. Overloading of nutrient in receiving waters can cause problems in downstream since excess amount of nitrogen (N) in aqua system causes eutrophication and rapid depletion of oxygen. Therefore, N compound often become a limiting nutrient for aquatic plant in water environment. In order to be able to lower effluent total nitrogen (TN) level, all forms of organic nitrogen including particulate, colloidal and dissolve organic nitrogen (DON) in treated effluent need to be removed. DON in treated effluent mainly consisted of non-biodegraded transformed nitrogen from cell degradation and activity in biological wastewater treatment process.

Treated effluent from biological wastewater treatment system contain a number of organic compounds delivered from different sources including slowly degradable organic in wastewater and microbial products released during substrate utilization. Soluble microbial product (SMP) is categorized into two sub-categories based on the types of bacterial metabolism by which it is originated, utilization-associated products (UAP) and biomass-associated products (BAP). UAP were produced directly from substrate utilization while BAP are all products originated from biomass hydrolysis. BAP is speculated to contribute for at least a part of effluent dissolved organic matters as DON and dissolved organic carbon (DOC). In biological treatment process, the factor which effect on biofilm characteristics should be influenced on DON, biodegradable dissolved organic nitrogen (BDON), SMP and effluent organic matter (EfOM). Therefore, the condition that impact on contribution of SMP on DON and BDON is important to study for better understanding of the relationship between microbial activity and DON to minimize effluent TN.

This research is divided into two main stages based on the experiments in order to investigate the contribution of SMPs on EfOM, namely, DON and dissolved organic carbon (DOC) and their biodegradability under different organic loading rate (OLR) and under stress condition by using Ampicillin. Synthetic domestic wastewater and raw primary effluent from Fargo wastewater treatment plant are used in this study for understanding the SMP as a part of effluent organic matter (EfOM).

Significance of Research

Nutrient contamination in receiving waters is a crucial issue. Understanding the composition of treated wastewater and its biodegradability are important since it is discharged to water body and travel to downstream. Understanding the characteristic of EfOM help to choose the proper treatment and not post the risk to stream water. This study will provide the better understanding of SMP as a part of EfOM in treated wastewater from attached growth biological treatment process because there are few studies on the SMP of EfOM from attached growth biological system. Other than study of characteristic of SMP and EfOM, biodegradability of EfOM will be study because EfOM is consider as nutrient sources for microbial in receiving water.

Significant Findings

- The amount of SMPs as protein and carbohydrate are increasing proportionally with OLR.
- Proteins are found as a major component of SMP form which consist of 50 - 80%.
- Temperature has an important component of the system.
- The amount production of protein is less than untaken protein by bacteria during biological treatment process.
- Humic acid can be found in both synthetic and raw primary effluent. However, humic acid concentration in raw primary effluent system is higher.
- Organic matter concentration in the effluent reduced since it was used as nutrient sources. However, the residue organic matter in effluent is more complex than influent organic matter due to the increasing of aromaticity.
- Protein amount is increasing along with Ampicillin concentration.
- Biofilm can absorb ampicillin and help protecting bacteria which makes initial Ampicillin concentration at 150 ppm is not yet completely kill nitrogen oxidizing bacteria.

Use of Mixers in Water Towers to Prevent Ice Formation and Improve Water Quality

Basic Information

Title:	Use of Mixers in Water Towers to Prevent Ice Formation and Improve Water Quality
Project Number:	2015ND294B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Water Supply, Treatment, Methods
Descriptors:	None
Principal Investigators:	Wei Lin

Publications

There are no publications.

Research Description

The purpose of this research is to determine the impacts mixing has on water tower water quality. Mixers are being added to drinking water storage tanks to eliminate thermal stratification and improve water quality. Mixers are also being used to prevent ice formation during winter.

Using a mixer is referred to as active mixing but typically passive mixing is used to eliminate thermal stratification and maintain water quality. Passive mixing is the act of cycling water storage tanks by filling and draining periodically. Often passive mixing is not enough to prevent thermal stratification, which can lead to water quality deterioration. Also passive mixing is often not enough to prevent ice formation.

The three water towers in Moorhead Minnesota are being studied to determine the impacts that mixing has on water quality in water towers. Water temperature data is being collected continuously from the towers at various depths. Also water quality samples are being collected from various depths. The samples are analyzed for total chlorine concentration, pH, turbidity, heterotrophic plate counts, ammonia, nitrite, and nitrate concentrations.

The temperature data and water quality data is analyzed by comparing the results from towers with mixers to towers without mixers. It is also analyzed by comparing the results in towers with mixers operating and then mixers not operating. These analyses will provide the data necessary to make conclusions about the impacts mixers have on water tower water quality.

Significance of Research

This research will be used to optimize the operation of Moorhead's water towers. Moorhead should be able to improve the water quality in their water towers with the results of this study. Other systems can also use this research to learn about the effects mixing has on water tower water quality. It can be used, as a guide to help systems decide if a mixer is needed in their water storage tanks. No other study has been conducted to determine the impact that mixers have on water tower water quality. So it cannot be assumed that mixers are the perfect solution to summer water quality issues and winter ice formation.

Significant Findings

Thermal stratification has been found in the towers without mixers or when the mixers were turned off. Also chloramine concentration gradient has been found in the towers but mixers seem to minimize this problem. Disinfectant decay can be increased by increased water temperature and water age. This has been verified in the water towers with the total chlorine and temperature data along with the hydraulic residence time trends developed for each tower.

Moorhead will be using hydraulic residence time goals to operate their towers for summer 2016. These goals should help Moorhead maintain water quality in the towers this summer. Comparisons

form 2015 data will be made to the 2016 data to determine the impact the operation changes have had on water tower water quality.

Evaluation of Onsite Wastewater Treatment Systems Sand Filters and Biological Treatment on Indian Reservations

Basic Information

Title:	Evaluation of Onsite Wastewater Treatment Systems Sand Filters and Biological Treatment on Indian Reservations
Project Number:	2015ND295B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	001
Research Category:	Engineering
Focus Category:	Treatment, Wastewater, None
Descriptors:	None
Principal Investigators:	Wei Lin

Publications

There are no publications.

The funding for this project was canceled because the fellowship recipient lost his eligibility. The funding was reassigned to Project Number 2015ND293B.

Glutaraldehyde Removal from Flowback and Produced Water Using Photolysis

Basic Information

Title:	Glutaraldehyde Removal from Flowback and Produced Water Using Photolysis
Project Number:	2015ND296B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Treatment, Surface Water, Groundwater
Descriptors:	None
Principal Investigators:	Khan Eakalak, Sivaguru Jayaraman

Publications

There are no publications.

Research Description

In unconventional oil and gas extraction, hydraulic fracturing has been applied to ensure high and prolonged production of oil and gas from shale deposits. This technology induces cracking network in low-permeability shale to allow trapped oil and/or gas flow to the production wells by injection of hydraulic fracturing fluid at extremely high pressure and flow rate. Primarily, due to this recently improved technique, North Dakota right now is the second largest crude oil producing state in the United States, with 314 million barrels of oil produced in 2013. After hydraulic fracturing, there are two types of waters discharged from the well along with oil and gas. These waters are flowback water, mostly hydraulic fracturing water, and produced water, naturally occurred shale water. Hydraulic fracturing fluid is mainly water (98-99%) and proppant (mostly sand, 1-1.9%); however, several chemicals are added to the water to increase hydraulic fracturing performance. Among the chemical additives, biocides are one of the most common additives in hydraulic fracturing fluid. After hydraulic fracturing, biocides are also periodically injected to the wellbores. They are used to prevent corrosion to the wells associated with microbial growth. Glutaraldehyde (GA) is the most common biocide used in shale fracturing accounting for 80% of all shale fracturing. It is a harmful chemical to environment, human and aquatic organisms, however, a portion of glutaraldehyde returns with flowback and produced waters making the waters more harmful to the environment. This study will investigate the capability of photolysis by UV light in removing glutaraldehyde in flowback and produced waters, since this technology has small footprints, easy to operate, and effective against organic compounds.

Significance of Research

This study helps in addressing an obstacle associated with flowback and produced waters treatment and disposal. After removing GA from flowback and produced waters, biological treatment, which is economical, will become viable for treatment of the waters for potential fracturing reuse, or will make the waters less harmful for disposal. The work provides an effective treatment scheme for a common biocide in flowback and produced waters.

Significant Findings

GA can be photolyzed by UV at all studied conditions, however the degradation rates of GA were different at different light intensity, pHs, initial concentrations and salt concentrations. The degradation rate of GA increased with the increasing incident light intensity and decreasing pH. Either increasing or decreasing in initial concentration, the degradation rates of GA were lower than that at 0.1 mM initial concentration of GA. Interestingly, different salt concentrations had different effect on GA degradation rates. At lower salt concentration, a notable retardation of GA degradation rate was observed, however, as salt concentration increase the degradation rate of GA was also increase.

Biopolymers for Phosphate Removal from Eutrophic Lakes

Basic Information

Title:	Biopolymers for Phosphate Removal from Eutrophic Lakes
Project Number:	2015ND297B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Methods, Treatment, Nutrients
Descriptors:	None
Principal Investigators:	Achintya Nayan Bezbaruah

Publications

1. Hossain, M.E., C.W. Lee, A. Bezbaruah, 2015, Iron Uptake from Bare and Phosphate-Laden Nano-Iron by Lactuca sativa Grown in Hydroponics, Sustainable Nanotechnology Organization Conference, November, 2015, Portland, OR. (Poster)
2. Hossain, M.E., C. Ritt, A. Bezbaruah, 2015, Iron Cross-linked Biopolymer Beads for Aqueous Phosphate Removal, North Dakota Experimental Program to Stimulate Competitive Research (ND EPSCoR) State Conference, April 22, 2015, Fargo, ND. (Poster)

Research Description

Phosphorus (P) is important for the growth of plants and microorganisms in most ecosystems. However, excess phosphorus in waterbodies leads to the overgrowth of algae and plant species, and, hence, eutrophication sets in. Phosphorus affects 42% of the lakes and 66% of the river and streams in the US. Municipal and industrial wastewaters are the major point sources that contribute to P build-up in the aquatic environment. Accelerated eutrophication not only impacts the aquatic life but indirectly hampers the economic progress of communities that rely on aquatic food and other resources.

Eutrophication of lakes is a major problem in North Dakota. North Dakota's major industry is agriculture and it is ranked first in the nation in the production of many crops, including spring wheat, durum, barley, sunflowers, dry edible beans, pinto beans, flaxseed, canola and honey. North Dakota is also an important producer of sugar beets, potatoes and oats. There are 1.7 million heads of cattle, 160,000 pigs, and 88,000 sheep in North Dakota. Farms and ranches occupy more than 39 million acres, almost 90% of North Dakota's land area (http://www.agclassroom.org). P- and N-containing fertilizers used in agriculture and runoff from animal feedlots and firms make North Dakota one of the eutrophication-prone states. According to the North Dakota Department of Health (NDDH), ~52% (87 lakes) of the assessed lakes are eutrophic and ~17% (29 lakes) are hypereutrophic. Most of the 95.5% of the lakes and reservoirs assessed, 56% are considered threatened. A threatened state means that the continuation of current water quality and/or watershed trends would make it unlikely that these water bodies will continue to support aquatic life and water can be used for human consumption. It is imperative to devise effective methods to remove excessive phosphate from water and wastewater. There is a significant gap in technology to remove low concentrations P from waters, specifically from eutrophic lakes.

In the present research, a novel biopolymer beads was synthesized and used for the first time for phosphate removal using sodium alginate biopolymer and $FeCl_2$, where Fe (II) was used as the crosslinking ions. The introduction of $FeCl_2$ enhances the versatility of the polymer beads. The prepared FCA polymer beads have exhibited good stability and excellent sorption performances.

Significance of Research

Phosphate is essential in terrestrial ecosystems. However, the problem lies in the fact that phosphate is lost from soil naturally over time and finds its way into aquatic bodies. The natural process is expedited by the injudicious activities of the humankind. The loss has significance because global food security is heavily dependent on phosphate. Therefore, the incessant loss of phosphate means the global food security will be in jeopardy considering the fact that the global reserves of phosphate is limited, and phosphorus production is controlled by a handful of countries. It is predicted that phosphate production rate is going to decline from sometime 2033. The magnitude of anthropogenic activities which has aggravated the eutrophication problem across the globe can be put into perspective by even only looking at the US scenario. About 286,600 tons of PO_4^{3-}-P is discharged to the US waters every year by the wastewater treatment plants; agriculture contributes ~4 million tons of PO_4^{3-}-P per year to water bodies; ~2 million tons of phosphorus comes from commercial fertilizer, and ~2 million tons of phosphorus are applied in manure (Litke, 1999). Other non-point sources, especially from animal agriculture, contribute ~1.2 million tons

of phosphorus to the US waters. 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 per year) and recreational use ($0.37-1.16 billion per year).

Currently there is no accepted method for phosphate removal from eutrophic lakes because most of the existing methods do not work when phosphate concentrations are low, which is the feature of eutrophic lakes. Sorption is the most attractive option for phosphate removal from aqueous media when phosphate concentrations are low. The sorption is a desirable option because of its simplicity in design, operational ease, and cost effectiveness; and a range of sorbents is also available for selection. Recently, bio-based materials, including polysaccharides (biopolymers) have been used as (ad)sorbents for removing pollutants. Biopolymers are unique materials because they are typically non-toxic for the ecosystem components, biocompatible, biodegradable, and polyfunctional; they are also abundant, inexpensive, renewable, and modifiable. In this study, iron cross-linked alginate biopolymer has been developed for removal of aqueous phosphate. Alginate biopolymer is attractive because of its biodegradability, hydrophilicity, presence of carboxyl and hydroxyl groups, low cost, natural origin, and renewable nature. The biopolymer developed in this research will enable us to alleviate eutrophication problem of North Dakota lakes resulting from both point and non-point sources of pollution. As a secondary output, this research will contribute towards generating a new source of phosphorus for agriculture, thereby contributing towards better crop production in North Dakota and global food security.

Significant Findings

1. Novel iron cross-linked alginate beads (FCA) were successfully used for aqueous phosphate removal using three different concentrations of phosphate (5, 50 and 100 mg PO_4^{3-}-P/L). About 97% phosphate was removed in 360 min from the aqueous solution by wet beads having an initial phosphate concentration of 5 mg PO_4^{3-}-P/L. With 50 and 100 mg PO_4^{3-}-P/L, the beads were found to remove ~76% and 24%, respectively in 360 min.
2. Environmentally important concentration (100 µg PO_4^{3-}-P /L) was also tested with FCA beads and very fast removal was achieved. Around 80% of phosphate was removed within 20 min.
3. No change in phosphate removal was observed in the presence of Cl^-, HCO_3^-, SO_4^{2-}, NO_3^- and natural organic matter (NOM).
4. No change in phosphate removal was observed from pH 4 to 9. The point of zero charge (PZC) was determined as 9.2 for FCA beads, which explained the mechanism and efficacy of FCA beads at different pHs.
5. Actual lake waters were used to investigate the feasibility of using these FCA beads in real life situation (e.g., in eutrophic lakes), and 100, 81, 100, 100, and 100% phosphate removal was achieved in 24 h from lake waters having initial phosphate concentrations of 20.09, 69.21, 20.09, 11.16, and 26.79 µg PO_4^{3-}-P/L, respectively.
6. Cost analysis was also done and FCA beads were found to be very competitive compared to other sorbents.
7. Overall findings from this research demonstrated the potential use of the FCA beads for reclamation of eutrophic lakes.

A Study of the Spatial and Temporal Characteristics of Drought and its Impact in

Basic Information

Title:	A Study of the Spatial and Temporal Characteristics of Drought and its Impact in
Project Number:	2015ND298B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Drought, Hydrology, Groundwater
Descriptors:	None
Principal Investigators:	G. Padmanabhan

Publications

1. Odabas. M., N. Leelaruban, H. Simsek, and G. Padmanabhan, 2014, Quantifying Impact of Droughts on Barley Yield in North Dakota, USA Using Multiple Linear Regression and Artificial Neural Network, Neural Network World, 24(4), 343-356.
2. Leelaruban, N., G. Padmanabhan, 2015, Droughts-Groundwater Relationship in Northern Great Plains Shallow Aquifers, in Proceedings of the World Environmental and Water Resources Congress, American Society of Civil Engineers, Reston, VA, 510-519.

Research Description

Drought is a complex phenomenon difficult to accurately describe, and context dependent. Understanding drought severity, frequency, duration, and spatial extent is critical in drought mitigation and planning. Impact of drought on various sectors has been long-recognized. Globally, emphasis on drought research is increasing because the current understanding of drought is relatively inadequate due to its complex characteristics and ways in which it impacts various sectors in relation to its severity, duration, frequency, and areal coverage. It is difficult to define drought because it is a spatially and temporally diffused phenomenon.

Droughts have significantly impacted North Dakota in the past. Agriculture is a significant part of North Dakota's economy. This sector is highly impacted by droughts and has experienced vast losses, and is vulnerable to future drought threats. North Dakota is a leading producer of many crops, including durum wheat, barley, spring wheat, sunflower, and dry edible beans. Groundwater is one of the most valuable resources in North Dakota, and many residents and industries rely on it. However, groundwater is vulnerable to drought. Understanding the groundwater level responses to drought is important in managing groundwater. Based on economic, environmental and agricultural considerations of North Dakota, it is imperative to monitor and study droughts.

This study seeks to understand the spatio-temporal drought characteristics, and impact of drought on two specific sector such as crop yield and groundwater resources. Data from the U.S Drought Monitor, (National Oceanic and Atmospheric Administration) NOAA National Climatic Data Center (NCDC), USDA National Agricultural Statistics Service (NASS), and U.S. Geological Survey Ground-Water Climate Response Network (USGS CRN) are used in the study. This study utilizes the Geographic Information System (GIS) and statistical tools to study the spatial characteristics of drought. The Artificial Neural Network (ANN) and regression analysis are used to study the relationship between drought and crop yield. The impact of drought on groundwater resources is studies using selected drought indices based on the severity and duration of drought.

Significance of Research

This research contributes to understand the spatio-temporal characteristics of drought, and assess the impact of drought on agriculture and groundwater sectors. There are many studies conducted on these issues. However, this study can be distinguished from previous studies based on the novel approaches using recent computational tools to address the problem. Especially, the recent development and availability of computational tools can help develop better understanding of drought. Understanding spatial behavior of drought is one of the key challenge in drought study. The characteristics of drought are mostly studied using drought indices that represent the drought conditions of specific spatial units. The drought indices are reported based on the computation from station wide meteorological and hydrological variables. The computation involves the interpolation and aggregation of the data for specific spatial unit which will introduce the uncertainty. An appropriate approach is necessary to model the spatial dependency of drought and interpolate. It is also important to quantify the uncertainty associated with considering drought as a regional phenomenon and how the uncertainty changes with different sizes of spatial units. This study addresses this issues and demonstrates a methodology to model the spatial characteristics of drought and quantify the uncertainty with different spatial scale. The spatial behavior of drought

across different spatial scale also captured. Impact of drought on crop yields for selected crops is studied using recent computational tools such as ANN. The impact of drought with different severity levels on crop yield is reported. The groundwater responses to drought has not been explored adequately. This study assesses the capability of current surface climate/drought indices in reflecting ground water responses for drought. The effect of duration on groundwater resources and lag time of groundwater level response to drought also studied.

Significant Findings

This study demonstrated the use of Geostatistical Analyst tools in ArcGIS to interpolate the station wide meteorological drought indices, and emphasized the variation of drought within a spatial unit using Standardized Precipitation Index (SPI) with one month time scale. The study also quantified the uncertainty while reporting drought at three different selected spatial scales such as county, climate division, and state; and showed that level of uncertainty is increasing with the size of spatial unit. The behavior of droughts under different spatial scales: national (Contiguous U.S.), region (High Plains), state (North Dakota, ND), climatic division (South Central, ND), and county (Grant, ND) and areas prone to different intensity categories based on the spatial coverages and occurrence frequency are identified. The relationship between drought and crop yield is modelled using ANN and statistical tools. The research demonstrated how ANN can be used effectively to model the drought-crop yield relationship. The linkage between drought and groundwater level also studied. The Palmer Hydrological Drought Index and 24 month-Standardized Precipitation Index have better correlation with groundwater levels than other drought indices and climatic variables. In addition, the duration of drought events were found to have significant influence on groundwater level response to drought.

Injectable Nanoparticle-based Permeable Reactive Barriers for Groundwater Contaminant Remediation

Basic Information

Title:	Injectable Nanoparticle-based Permeable Reactive Barriers for Groundwater Contaminant Remediation
Project Number:	2015ND299B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Groundwater, Treatment, Methods
Descriptors:	None
Principal Investigators:	Achintya Nayan Bezbaruah

Publication

1. Rashid, U.S., S. Simsek, A.N. Bezbaruah, 2015, Injectable Nanoparticle-Based Permeable Reactive Barriers for Groundwater Contaminant Remediation, North Dakota Experimental Program to Stimulate Competitive Research (ND EPSCoR) State Conference, April 22, 2015, Fargo, ND. (Poster)

Research Description

A novel polymer was used to coat nanoscale zero-valent iron (NZVI) particles to increase their sticking coefficient in the aquifer materials. Two dimensional transport study was done to study the dispersion and transport of bare and polymer-coated NZVI (CNZVI) in porous media under steady state conditions. The results from the 2-D transport study were used to determine if coated NZVI particles could be the potential candidates for creating permeable reactive barriers (PRBs) in the subsurface at different flow velocities and different porosity. TCE and nitrate were selected as test contaminants to evaluate their removal efficiency by both bare NZVI and CNZVI. A bench scale PRB system was made to investigate the efficiency of polymer-coated NZVI as a reactive material in PRB for nitrate and TCE removal.

Significance of Research

Trichloroethylene (TCE) is a widely used organic solvent for electronic, metal finishing, machinery, and dry cleaning application. As a result of improper waste disposal practices, TCE has become one of the most problematic classes of volatile organic compounds found in groundwater. TCE plumes can migrate several kilometers from their sources depending on the sorption capacity of aquifer materials and reactivity of TCE. An incredible number of sources contribute to groundwater nitrate (NO_3^-) contamination, including fertilizers, septic systems, and industrial atmospheric pollution. Exposure to this contaminant has been implicated in cancers, such as non-Hodgkins lymphoma, and neonatal disease, including blue baby syndrome. The use of NZVI for the treatment of contaminated soil and groundwater is increasingly being popular. NZVI can treat contaminant plumes and the source significantly because of their high surface area to volume ratio, rapid kinetics, and high reactivity. However, bare NZVI agglomerates and settles quickly in aqueous environment, which reduces the available surface area for reduction to occur. To improve the colloidal stability of NZVI, surface modification is used. Surface modification increases the repulsive forces between particles. To prepare physically more stable and chemically more reactive NZVI, different polymers have been used for coating. These polymer coated NZVI not only improve the colloidal stability but also improve contaminants degradability of NZVI very efficiently. However, limiting factors such as, high cost, limited biodegradability, difficulty in the in-situ application have limited the use of these coated polymers.

Many studies (one and two dimensional) have reported successful transport of surface modified NZVI. This transport behavior has limited the use of surface modified NZVI in permeable reactive barriers (PRBs). The objective of this research is to prepare a novel polymer, which will not only be cost effective but also environmentally friendly and can use as a reactive material in PRB for removing TCE and nitrate efficiently. The technique can be applied in both surface and groundwater remediation. This type of system is very suitable for in-situ groundwater remediation because of low cost. As there are a number of TCE and nitrate contaminated sites in the state, the research results will benefit North Dakota.

Significant Findings

- The polymer has successfully increased the colloidal stability of NZVI in water. After 2 hours 70% of CNZVI particles remain suspended whereas 10% of bare NZVI particles remain suspended.
- The 2-D transport study showed that, even at highest velocity, the coated NZVI particles did not move in porous media as surface modification has increased the sticking coefficient of NZVI particles in the aquifer material.
- The nitrate treatability studies showed similar NO_3^- - N reductions with CNZVI compared to bare NZVI for the same initial concentrations and the same reaction time.
- The CNZVI particles need to have long shelf life to be commercially viable (storage and transportability requirements). The shelf-life study showed that the NO_3^- - N degradation rate remained more or less unchanged for 4 months.

Quantifying Soluble Salt Removal from Subsurface Tile-Drain Agricultural Fields

Basic Information

Title:	Quantifying Soluble Salt Removal from Subsurface Tile-Drain Agricultural Fields
Project Number:	2015ND300B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Agriculture, Nutrients, Methods
Descriptors:	None
Principal Investigators:	Francis Xavier McKeon Casey, Abbey Foster Wick

Publication

1. Schewe, R., F.X.M. Casey, A.F. Wick, 2015, Water Flow Characteristics of a Shrink-Swell Soil from a Wetting and Drying Cycle. Annual ASA-CSSA-SSSA Meetings, November 17, 2015, Minneapolis, MN. (Poster)

Research Description

Installation of subsurface tile drainage has increased dramatically in the Red River Valley (RRV) of the north. Tile drainage intercepts water from above and below the tile drain, increasing the rooting depth of soils. Tile drainage also prevents further accumulation of salts in the upper soil profiles by intercepting rising water tables that contain higher concentration of geogenic salts naturally found in parent materials. Whereas, water intercepted from above the tile drains will contain leached salts that have accumulated in the root zone, decreasing soil salinity. This research was developed to quantify salt removal from above the tile drain with leaching water.

In order to determine the salt removed from above the tile drain, six large cores (20 cm dia, 121 cm length) were extracted from the Soil Health and Agriculture Research Extension (SHARE) farm located near Mooreton, ND. The length of each core is indicative of installed tile drainage in the field. Three cores were extracted from a relative high salt location (EC_e=5.36 dS $m^{-1)}$, and three cores were extracted from a relative low salt location (EC_e=0.84 dS m^{-1}). Leaching experiments were performed under an accelerated wet/dry soil regime to mimic the semi-arid field conditions of North Dakota. After the application of water, leachate was collected and analyzed for salt constituents including Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, SO_4^{2-}, and Cl^{-}. Additionally, elbow tensiometers and microsamplers were installed at four different depths (0-20 cm, 20-53 cm, 53-81 cm, and 81-121 cm), representative of pedon classification by the Natural Resources Conservation Service (NRCS) (NRCS, 2014). Elbow tensiometers measurements determined the progress of water transfer through the soil monoliths. Also, microsamplers extracted soil water from within the core to provide solute transport data as the water was leached through the soil. A total of four wet/dry cycles were completed to provide sufficient data for the research goals.

Significance of Research

A recent wet cycle in North Dakota has induced soil salinization from rising groundwater tables. Soil salts within the groundwater are deposited near the soil surface through capillary rise of soil water (Franzen, 2007; Euliss and Mushet, 2011). When the soil water is evapotranspired, salt will precipitate and accumulate in the soil rooting zone, which can severely impact agricultural production by inducing ion toxicity and drought stress (Katerji et al., 1997).

Reversing the salinization process is a difficult task in a semi-arid climate. Precipitation events and spring groundwater recharge are the only sources of natural fresh water that have the potential to solubilize and leach salts deeper in the soil profile. Therefore, producers of the RRV have implemented tile drainage to manage and reverse the effects of soil salinity in their fields. However, the efficiency of salinity reduction with tile drainage is unknown. This research focuses on quantifying the removal of salt from leaching water in RRV Fargo clay soils to provide producers with localized research results to better understand tile drainage as a tool to reduce soil salinity.

Significant Findings

Significant findings of this research include the dominate flow path of water through dry, smectitic clay soils and quantification of salt removal from a total of four leaching events. After water was

applied to the surface of the soil cores, the tensiometer pressure head readings indicated that all core depths approached near-saturated values within 24 hr, indicating the water flow advanced rapidly, over 4000× greater than was expected in this soil texture. The rapid water flow was indicative of water transfer through highly structured soils or through preferential flow pathways, perhaps desiccation cracks which are common in these vertic soils. Salt removal from leaching events include 0.23% (s=0.02) removal from areas of relatively high salt (EC_e=5.36 dS m^{-1}) and 0.06% (s=0.004) removal from areas of relatively low salt (EC_e=0.84 dS m^{-1}). Implementation of tile drainage in the RRV will remove a fraction of salt with each leaching event. However, leaching events in the RRV are limited and management practices to improve soil structure and water transfer to the tile drain may increase drainage events (Oster et al., 1996). Management efforts to improve infiltration may maximize the efficiency of salt removal by tile drainage (Callaghan et al., 2014). For example, cover cropping can improve infiltrability of precipitation and break confining layers that impede water movement (Chen et al., 2014). No-till techniques can reduce compaction layers obstructing water flow towards the tile drain (Okada et al., 2014). Although management practices can improve water transfer, leaching events that occur in the field are weather dependent (Wiekenkamp et al., 2016). Thus, subsequent salt removal per season is difficult to predict; however, salt removal will occur with each leaching event and improve the soil salinity status.

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Evaluation of Bioavailable Dissolved Organic Nitrogen Using Various Algal Species

Basic Information

Title:	Evaluation of Bioavailable Dissolved Organic Nitrogen Using Various Algal Species
Project Number:	2015ND301B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Nitrate Contamination, Nutrients, Surface Water
Descriptors:	None
Principal Investigators:	Halis Simsek

Publication

1. Sun, Jingyi, 2015, Bioavailability and Biodegradability of Dissolved Organic Nitrogen Originated from Municipal and Animal Wastewater, MS Thesis, Department of Agricultural and Biosystems Engineering, College of Agriculture, Food Systems, and Natural Resources, North Dakota State University, Fargo, ND, 85 pages.

Research Description

Dissolved organic nitrogen (DON) from final effluent of WWTPs and animal feedlots from agricultural areas are important nutrient sources for bacterial and algal communities in surface waters such as rivers, lakes, and estuaries. Excess amount of DON in surface waters can cause excess algal growth and dissolved oxygen depletion and ultimately cause eutrophication in water ecosystem. Bioavailable DON (ABDON) is a fraction of DON that is directly or indirectly available as a nitrogen source for algal species through hydrolysis process. Determine the ABDON level in municipal and animal wastewater will help to understand the environmental impact of DON to local water bodies.

In the first part of the study, DON and ABDON levels from the city of Fargo wastewater treatment plant (WWTP) were determined. The city of Fargo WWTP has an average flow of fifteen million gallons of wastewater per day. The plant operates a trickling filter process which includes removal of biochemical oxygen demand (BOD), carbonaceous BOD and ammonia nitrogen (NH_3-N). Final effluent contains high amount of nitrate, which has been discharged into the Red River. Approximately more than 40% of influent DON in final effluent cannot be removed in the treatment plant using current trickling filter technology. Hence, to improve the quality of surface waters in ND and prevent eutrophication, it is necessary to understand the impact of nitrate and ABDON from the effluent to the environment. This study provides important outcomes to reduce effluent nitrate and organic nitrogen prior to discharge. Besides, in the future, regulatory agencies might force Fargo WWTP to reduce effluent total nitrogen under 10 mg/L. Using algae in a proper stage of the treatment plant helps to reduce effluent TDN with low cost.

In the second part of the study, DON from two animal wastewater sources have been studied under bioassay conditions. TDN level in animal wastewater can reach to thousands in mg-N/L, while N mainly existed in the form of ammonia and organic nitrogen. The organic load from animal wastewater is much higher than domestic sewage wastewater. However, most studies focus on reduction of ammonia and nitrate. Further studies are necessary to investigate the effects of animal wastewater DON to aquatic and soil environment.

The main scope of this study was to collect DON and ABDON data from three locations of a WWTP and two locations from animal feedlots in order to: a) investigate DON and ABDON for three different algae species in a two-stage trickling WWTP, an animal feedlot, and a sheep lagoon. b) examine mixed culture algae and algae + bacteria interactions for two different algal species to determine the best algal species to utilize ABDON.

Along with bacteria, two algal species, *C. reinhardtii* and *C. vulgaris*, were used as an inoculum for animal wastewater samples while in addition to these bacteria and two algae, *Selenastrum capricornutum* was used as well as an inoculum for Fargo WWTP samples. All the samples were incubated for 21 days to determine ABDON or BDON. Dissolved ammonia N (DNH_3-N), dissolved nitrite N (DNO_2-N), dissolved nitrate N (DNO_3-N), and TDN were analyzed before and after the incubation. Data from this research will help to understand the bioavailability of DON from Fargo WWTP and from animal feedlots in ND and their impact to local waterbodies.

Significance of Research

This research provides important outcomes to improve the quality of Red River in North Dakota by minimizing the nutrient entrance to the river either from WWTPs or from animal feedlots. For the first time, different algal species were used to examine the bioavailability of dissolved organic nitrogen in a two-stage trickling filter WWTP and two animal wastewater sources. Determining the BDON and ABDON levels with pure-cultured and/or mixed cultured algae helps to understand the environmental impact and eutrophication potential. In addition, investigating the removal efficiency of ABDON by comparing with different species and different sampling locations may provide data to find an approach to reduce nitrogen discharges from WWTP and animal wastewater to local waterbodies. Findings of this project were presented in a national or regional conference and will be submitted for publication in a peer reviewed journal. A final report containing all the information on the project including raw data will be delivered at the end of the project.

Significant Findings

This study provides important insight on bioavailability of DON using three different algal species (*S. capricornutum, C. reinhartti* and *C. vulgaris*) with/without bacteria addition in wastewater samples collected from different source of municipal and animal wastewater. In the municipal WWTP treatment train, the initial ABDON was around 6.48 mg-N/L and the final ABDON was reduced to 2.84 mg-N/L indicating that 64% of ABDON was reduced in the biological treatment and 66% of bioavailable BDON was removed in TFs. ABDON in algae-only seeded samples were quite low compare to algae + bacteria seeded samples proved the symbiotic relationship between algae and bacteria. For animal wastewaters, the samples were inoculated using two types of pure culture algal species (*C. reinhardtii* and *C. vulgaris*) and bacteria (MLSS). The results showed that from 3.21 to 5.87 mg-N/L of DON (compromised about 51.3% to 78.9% of initial DON) in animal feedlot effluent and from 3.44 to 7.54 mg-N/L of DON (compromised about 40.5% to 80.9% of initial DON) in lagoon samples were bioavailable to any combination of algae and bacteria. In both types of wastewater, at least 20% of initial DON was recorded as recalcitrant DON. This portion of DON could be degraded in longer incubation conditions, which could be in receiving water.

The Role of Algal Species on Phosphorus Bioavailability

Basic Information

Title:	The Role of Algal Species on Phosphorus Bioavailability
Project Number:	2015ND302B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Nutrients, Surface Water, Wastewater
Descriptors:	None
Principal Investigators:	Khan Eakalak

Publication

1. Swanson, M., M. Kasi, E. Khan, 2015, Sensitivity of Phosphorus Bioavailability Tests to Algal Species, in Proceeding 88th Annual Water Environment Federation Technical Exposition and Conference, Water Environment Federation, Alexandria, VA.

Research Description

Eutrophication of waters is one of the major issues society faces, it degrades water quality and can lead to dead zones such as in the Gulf of Mexico. Phosphorus is one of the key nutrients that lead to eutrophication when sufficient concentrations are present in water bodies. However it is the bioavailable phosphorus (BAP) that is of real concern, because this is the phosphorus algae use to grow. *R. subcapitata* has been the standard algal species utilized to estimate BAP. This study will utilize two additional species, C. *vulgaris* and C. *reinhardtii*, for the comparison of BAP estimates. It is hypothesized that BAP differs between different algal species as organisms fill different niches in ecosystems. There is little research concerning BAP especially in the area of environmental engineering. This research will further our understanding of phosphorus and how it is utilized by algae after being discharged and can impact how future nutrient standards are managed.

Samples have been analyzed for P-species before and after the incubation period to determine which P-species *R. subcapitata* utilize to grow, maintain themselves, and reproduce. Samples have been analyzed via different algal species, individually and as a mixed culture, to determine the BAP concentrations of different algal species. Results show that each P-species: soluble reactive phosphorus (SRP), soluble acid-hydrolysable phosphorus (SAHP), and dissolved organic phosphorus (DOP) of secondary wastewater effluents contribute to the BAP concentration. Results also show that BAP concentration are not significantly different when measured via different algal species, following a one-way ANOVA test [$F(3, 41) = 2.12$, $P = 0.113$]. The thesis report has been written, edited by my adviser, and is being edited by the Graduate School.

Significance of Research

Results will show whether BAP estimates vary between different algal species. If results vary this research will show that the current standard algal species of *R. subcapitata* is not necessarily a reliable estimate of BAP and that other algal species may provide a higher estimate of BAP. The research will also show how the algal species affect the concentration of the different P-species from multiple WWTP effluents.

Significant Findings

No significant difference of %(BAP/TDP) was found among the algal species as individual species or a mixed culture. Therefore, any of the algal species tested could be used to measure BAP and produce comparable results. While any of the algal species tested could be used in the bioassay method to produce comparable results, it is recommended that *R. subcapitata* remain the standard algal species because this species provided slightly higher BAP concentrations and would therefore provide more conservative BAP estimates than the other algal species.

All P-species were shown to be partially bioavailable due to the decrease seen in all bioassays for SRP and SAHP and in some bioassays for DOP over the incubation period. SRP contributed to the majority of the BAP concentration, comprising 91% and 97% of BAP in the Fargo and Moorhead WWTP samples, respectively. These results indicate that both WWTPs are discharging effluents with readily bioavailable P.

The bioavailability of each P-species was also determined. SRP and SAHP were approximately 95% and 75% bioavailable for the samples from both WWTPs. The bioavailability of DOP differed, being 33% and 0% bioavailable for the samples from the Fargo and Moorhead WWTPs, respectively.

A relation between P-species and BAP could not be made according to a regression analysis. However, it is possible to use SRP as a low BAP estimate and TDP or TP as a high BAP estimate. This allows for a quicker and more cost effective method of estimating BAP compared to bioassays. Results suggest that the WWTPs studied should focus on removing SRP and SAHP in order to reduce BAP, as their bioavailabilities were high. This could be accomplished by incorporating biological P removal or chemical P precipitation and clarification after the secondary biological processes, in order to remove most of the remaining SRP from the effluent and thereby reducing the BAP concentration.

Information Transfer Program Introduction

Information dissemination is done through an annual newsletter, and presentations and publications by grant and fellowship recipients. A website also helps disseminating institute research information. The institute's website address is http://www.ndsu.edu/wrri. Past newsletters can be accessed through the institute web site. Technical reports of Fellowship projects authored by the Fellows and advisers are also placed on the institute website.

Information Dissemination and Communication

Basic Information

Title:	Information Dissemination and Communication
Project Number:	2015ND303B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	001
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	Khan Eakalak

Publications

There are no publications.

Activities to disseminate information related to the Institute and research under this project included:

1. Maintaining website as an effective way communicating to the public
2. Publishing the annual institute newsletter
3. Publishing Fellowship and other research done through the Institute
4. Hosting the annual "Distinguished Water Seminar"
5. Presenting research results by affiliated faculty and Fellows
6. Sponsoring or co-sponsoring local or regional conferences

The website of the Institute was updated at least quarterly, and more often when a research project wished to provide updates or when a Fellow graduates. The website provides additional details on the research. The list of Institute Affiliate Faculty with their expertise was updated. Research reports published by the institute were placed on this website as and when they became available. The institute website is: http://www.ndsu.edu/wrri.

The Institute continued its annual newsletter, which highlighted the graduate research fellowship program, the research grants associated with it, and general summaries of ongoing research. The newsletter profiled institute research and researchers and published other newsworthy water issues in the State.

The Institute also encouraged its Fellows and affiliated faculty to present their work at seminars and conferences. Here is a list of seminar and conference presentations made by Fellows and affiliated faculty.

1. Dandumrongsin, B., H. Simsek, C. Rongsayamanont (2015). Characterization of soluble microbial products and its contribution on dissolved organic matters in municipal wastewater effluent. International Prairie Student Conference, August 13-14, 2015, Brookings, SD.
2. Dandumrongsin, B., H. Simsek (2015). A method to determine biodegradability of organic nitrogen using laboratory scale column system. North Dakota Experimental Program to Stimulate Competitive Research (ND EPSCoR) State Conference, April 22, 2015, Fargo, ND. (Poster presentation)
3. Hossain, M.E., C.W. Lee, A. Bezbaruah (2015). Iron uptake from bare and phosphate-laden nano-iron by Lactuca sativa grown in hydroponics, Sustainable Nanotechnology Organization Conference, November, 2015, Portland, OR. (Poster presentation)
4. Hossain, M.E., C. Ritt, A. Bezbaruah (2015). Development of biopolymer-based slow-release phosphate and iron fertilizers, World Environmental & Water Resources Congress, May, 2015, Austin, TX.
5. Hossain, M.E., C. Ritt, A. Bezbaruah (2015). Iron Cross-linked biopolymer beads for aqueous phosphate removal, North Dakota Experimental Program to Stimulate Competitive Research (ND EPSCoR) State Conference, April 22, 2015, Fargo, ND. (Poster presentation)
6. Leelaruban, N., G. Padmanabhan (2016). Impact of droughts on groundwater sources. The Environmental and Water Resources Institute of the American Society of Civil Engineers (ASCE-EWRI) -International Perspective on Water Resources and the Environment (IPWE) Conference, January 4-6, 2016, Colombo, Sri Lanka.
7. Leelaruban, N., G. Padmanabhan (2015). Droughts-groundwater relationship in northern Great Plains shallow aquifers. World Environmental and Water Resources Congress, May 17-21, 2015, Austin, TX.

8. Leelaruban, N., H. Simsek, M. Odabas, A. Akyüz, G. Padmanabhan (2015). Effect of drought on corn (Zea Mays L.) yield in North Dakota, USA. ASABE Annual International Meeting, July 26-29, 2015, New Orleans, LA.

9. Rashid, U.S., S. Simsek, A.N. Bezbaruah (2015). Injectable nanoparticle-based permeable reactive barriers for groundwater contaminant remediation, North Dakota Experimental Program to Stimulate Competitive Research (ND EPSCoR) State Conference, April 22, 2015, Fargo, ND. (Poster presentation)

10. Roy, D., X. Jia, D. Steele, X. Chu (2015). Measurement and simulation of infiltration rates into undrained and subsurface drained soils. 2015 ASABE Annual International Meeting, July 26-29, 2015, New Orleans, LA. (Roy, D. is a fellow supported by NDSWC matching fund)

11. Roy, D., X. Jia, D. Steele (2015). HYDRUS model simulation of infiltration rates into undrained and tile drained soils. North Central ASABE Conference, April 10-11, 2015, Fargo, ND. (Roy, D. is a fellow supported by NDSWC matching fund)

12. Schewe, R., F.X.M. Casey, A.F. Wick (2015). Quantifying salt removal from tile drainage in the Red River Valley. Annual ASA-CSSA-SSSA Meetings, November 18, 2015, Minneapolis, MN.

13. Schewe, R., F.X.M. Casey, A.F. Wick (2015). Water flow characteristics of a shrink-swell soil from a wetting and drying cycle. Annual ASA-CSSA-SSSA Meetings, November 17, 2015, Minneapolis, MN. (Poster Presentation)

14. Sharma, S., M.H. Ademola, H. Simsek (2015). Impact of solids retention time on wastewater derived bioavailable dissolved organic nitrogen. ASABE Annual International Meeting, July 26-29, 2015, New Orleans, LA. (Sharma, S. is a fellow supported by NDSWC matching fund)

15. Sharma, S., M.H. Ademola, H. Simsek (2015). Wastewater treatment using microalgae Chlamydomonas Reinhardtii and bacteria in a continuous flow stirred-tank reactor (CSTR). North Dakota Experimental Program to Stimulate Competitive Research (ND EPSCoR) State Conference, April 22, 2015, Fargo, ND. (Sharma, S. is a fellow supported by NDSWC matching fund) (Poster presentation)

16. Shoghli, B., Y.H. Lim (2015), Predictive scheme for failures of embankment dams with high overtopping potential: Case studies using remote sensing data. World Environmental & Water Resources Congress, May, 2015, Austin, TX. (Shoghli, B. is a fellow supported by NDSWC matching fund)

17. Shoghli, B., Y.H. Lim (2015). Comparative study for evaluating the soil moisture in improving flood forecasting. North Dakota Experimental Program to Stimulate Competitive Research (ND EPSCoR) State Conference, April 22, 2015, Fargo, ND. (Shoghli, B. is a fellow supported by NDSWC matching fund) (Poster presentation)

18. Silvis, B. (2015). The Impact of policy and economic drivers of corn production on nitrogen levels of the Buffalo River subbasin, Minnesota, 2006-2014." Geological Society of America North-Central Section Meeting, May, 2015, Madison, WI. (Silvis, B. is a fellow supported by NDSWC matching fund)

19. Silvis, B., H. Zheng (2015). Policy and economic forces driving nitrate level changes in Buffalo River Subbasin, MN. North Dakota Experimental Program to Stimulate Competitive Research (ND EPSCoR) State Conference, April 22, 2015, Fargo, ND. (Silvis, B. is a fellow supported by NDSWC matching fund) (Poster presentation)

20. Sun, J., J. Ohm, M. Blonigen, H. Simsek (2015). Evaluation of bioavailable dissolved organic nitrogen in municipal wastewater using algae Chlamydomonas reinhardtii and Chlorella vulgaris. 88th Annual Water Environment Federation Technical Exposition and Conference (WEFTEC), September 26-30, 2015, Chicago, IL.
21. Swanson, M., M. Kasi, E. Khan (2015). Sensitivity of Phosphorus bioavailability tests to algal species. 88th Annual Water Environment Federation Technical Exposition and Conference (WEFTEC), September 26-30, 2015, Chicago, IL.
22. Torres, L., O.P. Yadav, E. Khan (2016). Risk assessment of surface water contamination due to Pb-210 in oil produced water from the Bakken, ND. 3-Minute Thesis (3MT™) Competition, February, 2016, Fargo, ND. (Torres, L. is a fellow supported by NDSWC matching fund)
23. Torres, L., O.P. Yadav, E. Khan (2015). Risks associated with water and wastewater management in unconventional oil and gas production. Poster presented at the 2015 Water Quality and Technology Conference & Exposition, November, 2015, Salt Lake City, UT. (Torres, L. is a fellow supported by NDSWC matching fund) (Poster presentation)
24. Wamono, A., D. Steele, Z. Lin, T. DeSutter, X. Jia, D. Clay (2015). Effects of gypsum and sugarbeet spent-lime application on the hydraulic properties of subsurface drained saline-sodic soils. ASABE Annual International Meeting, July, 26-29, 2015, New Orleans, LA. (Wamono, A. is a fellow supported by NDSWC matching fund)

There are also publications that were generated from the matching fund from NDSWC during or prior to the reporting period. These publications cannot be reported via the Online Program Management System (niwr.net) because the projects were funded solely by the matching fund and therefore there are no project numbers associated with the projects. These publications are as follows.

1. 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.
2. Fisher, J. (2015) Northern leoaprd frogs in North Dakota: assessing the conservation status of a widespread amphbian species. Ph.D. Dissertation, Environmental and Conservation Sciences Program, College of Graduate and Interdisciplinary Studies, North Dakota State University, Fargo, ND.
3. Gbolo, P., P. Gerla (2015) Spatiotemporal distribution of soil nutrients within an abandoned cattle feedlot. Journal of Soils and Sediments, 15, 71-80.
4. Gbolo, P. (2014) Quantifying phosphorus cycling and fate within an abandoned feedlot and adjacent wetlands. Ph.D. Dissertation, School of Geology & Geological Engineering, College of Engineering and Mines, University of North Dakota, Grand Forks, ND.
5. Fisher, J., D. Mushet, C. Stockwell (2014) Potential for parasite-induced biases in aquatic invertbrate population studies. Hydrobiologia, 722, 199-204.
6. Gbolo, P., P. Gerla (2013) Statistical analysis to characterize transport of nutrients in groundwater near an abandoned feedlot. Hydrology and Earth System Sciences, 17, 4897-4906.

Fifth 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 of Civil and Environmental Engineering at

Arizona State University in Tempe, Arizona. Dr. Westerhoff, is also the Senior Advisor to the Provost for Engineering & Science and the co-PI for National Science Foundation Engineering Research Center "Nantechnology Enabled Water Treatment Systems." The title of his presentation was "Water Information Technology: Modeling DeFacto Wastewater Reuse across the USA."

Dr. Westerhoff's presentation focused on the magnitude of the contribution of municipal wastewater to potable water supply (unintentional wastewater reuse) and its implications. It was well attended by affiliated faculty and Fellows, and NDSU faculty and students in general.

USGS Summer Intern Program

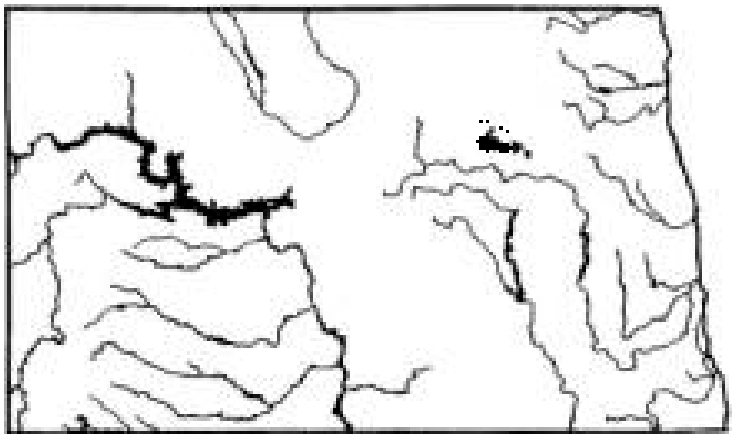
None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	0	0
Masters	8	0	0	0	8
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	10	0	0	0	10

Notable Awards and Achievements

Publications from Prior Years

1. 2009ND191B ("Fate of Biodegradable Dissolved Organic Nitrogen in Fargo Wastewater") - Articles in Refereed Scientific Journals - Simsek, H., T. Wadhawan, E. Khan, 2013, Overlapping Photodegradable and Biodegradable Organic Nitrogen in Wastewater Effluents, Environmental Science and Technology, 47(13), 7163-7170.
2. 2009ND191B ("Fate of Biodegradable Dissolved Organic Nitrogen in Fargo Wastewater") - Articles in Refereed Scientific Journals - Simsek, H., M. Kasi, J.-B. Ohm, M. Blonigen, E. Khan, 2013, Bioavailable and Biodegradable Dissolved Organic Nitrogen in Activated Sludge and Trickling Filter Wastewater Treatment Plants, Water Research, 47(9), 3201-3210.
3. 2009ND191B ("Fate of Biodegradable Dissolved Organic Nitrogen in Fargo Wastewater") - Articles in Refereed Scientific Journals - Simsek, H., M. Kasi, T. Wadhawan, C. Bye, M. Blonigen, E. Khan, 2012, Fate of Dissolved Organic Nitrogen in Two Stage Trickling Filter Process, Water Research, 46(16), 5115-5126.
4. 2014ND283B ("Three Dimensional Analyses of Flow Dynamics & Chlorination of Ground Water Supply Reservoir in a Cold Region") - Dissertations - Deering, Derrick, 2015, Thermo Effects to Ground Water Reservoirs in Water Distribution Systems Experiencing Cold Climate and Efficient Preventative Measures, ME Thesis, Department of Civil Engineering, College of Engineering and Mines, University of North Dakota, Grand Forks, ND.



North Dakota
Water Resources Research Institute

North Dakota State University
University of North Dakota

ANNUAL REPORT
SUPPLEMNTAL MATERIALS

March 1, 2015 to February 29, 2016

Fiscal Year 2015 Report (Supplemental Materials)
to the U.S. Geological Survey

June 1, 2016

Annual Report
Supplemental Materials

Fiscal Year 2015 Report (Supplemental Materials) to the U.S. Geological Survey

Grant No. 1434-HQ-96-GR-02696
U.S. Geological Survey

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

June 1, 2016

Table of Contents

INTRODUCTION

This report provides supplemental materials to the Fiscal Year 2015 Report to the U.S. Geological Survey (USGS). The supplemental materials are progress reports for projects solely funded by the North Dakota State Water Commissioner (NDSWC) which provided matching fund to the base grant (104B) from USGS. For the Fiscal Year 2015, six out of sixteen projects were solely funded by NDSWC and their progress is described below.

Project Title: Snowmelt water infiltration into frozen soils in the Red River of the North Basin

Fellow: Debjit Roy
Adviser(s): Dr. Xinhua Jia, Agricultural and Biosystems Engineering Department, NDSU
Start Date: 03/01/2015
End Date: 02/29/2016

Publication

Roy D., X. Jia, D. Steele, X. Chu (2015). Measurement and simulation of infiltration rates into undrained and subsurface drained soils. ASABE Paper No. 152190011. St. Joseph, Michigan, ASABE.

Presentation

Roy, D., X. Jia, D. Steele, X. Chu (2015). Measurement and simulation of infiltration rates into undrained and subsurface drained soils. 2015 ASABE Annual International Meeting, July 26-29, 2015, New Orleans, LA.

Roy, D., X. Jia, D. Steele (2015). HYDRUS model simulation of infiltration rates into undrained and tile drained soils. North Central ASABE Conference, April 10-11, 2015, Fargo, ND.

Research Description

Snowmelt water infiltration into frozen soil is an important but complicated process that can affect surface water runoff and groundwater recharge. Many factors, such as soil moisture, soil temperature, water release rate from the snow cover, energy content of infiltrating water, porosity, soil cracks, presence or absence of macropores and also complex processes of heat and mass transfer through the frozen soils, affect the total infiltration process into frozen soils. In northern hemisphere, nearly 60 percent of the land surfaces are seasonally frozen and North Dakota is a part of that area. There is no simple and clear answer on how water infiltrates into frozen soil. The lack of understanding of the infiltration process into frozen soil is the major limiting factor affecting spring flood forecasting. In recent years, during the spring flood events in the Red River of the North Basin (RRB), flood forecasting cannot be estimated accurately due to lack of data on infiltration into frozen soil. Any error in flood prediction can cause significant financial losses and threaten 200,000 people lives in the Fargo-Moorhead metro area as well as people and animals in the entire basin. The proposed research project will focus on snowmelt infiltration characteristics into frozen soils. A snowmelt water infiltration model will be developed which can help to overcome the current obstacles in order to accurately predict spring flood.

Significance of Research

Understanding the infiltration process into frozen soils could have a broad impact to the hydrological field for the entire and especially in permafrost regions. It would help to better understand the runoff processes and flooding events in winter and spring. Properly adjusted

numerical infiltration model could be used to predict actual runoff peaks to prevent damage from floods or to prevent overestimation of runoff. The benefit from this proposed study will be several million dollars each year in flood preparation.

Significant Findings

In total, twenty one infiltration field tests were conducted in tile drained and undrained fields of North Moorhead, MN and Fairmount, ND sites using Cornell sprinkler infiltrometer in frozen and unfrozen fields in 2014 and 2015. Soil moisture contents were recorded during the tests using Hydra Probe II sensors. Six soil box infiltration experiments were conducted in 2015. A wooden box (50 cm L, X 50 cm W X 30 cm D) was packed layer by layer with field soil for each experiment by maintaining a same soil bulk density. Soil moistures at field capacity, at halfway between permanent wilting point and field capacity; and at wilting point are taken as moisture treatments for the experiments. 5TE soil moisture and temperature sensors (Decagon Devices) have been installed at 11, 17, and 23 cm depth of the soil box. The soil moistures and temperatures are continuously recorded by a datalogger during the experiment period. Infiltration experiments were carried out using Cornell sprinkler infiltrometer until infiltration water reaches the bottom soil moisture sensor. Soil physical properties were determined using soil cores collected from the field. Soil water release curves (SWRC) were determined using Hyprop (Version 10/2011, UMS GmbH Munchen) and WP4 Dewpoint Potentiometer (Version 1.1, Decagon Devices, Inc.) method. SWRCs were developed by using the van Genuchten (1980) equation. Soil matric potential and water content data measured by combined method of HYPROP and WP4 methods were plotted together as matric potentials vs volumetric water content. Best fit soil parameters (α, n and m) were estimated for van Genuchten equation using "Excel Solver" (Wraith and Or, 1998). In both HYDROL-INF and HYDRUS models, soil physical properties are very needed for simulation scenarios. The field infiltration measurements were compared to simulated results from the modified HYDROL-INF (Version 7.00) infiltration model (Chu and Marino, 2006). Also the measured cumulative infiltration values were compared to the simulated results from HYDRUS model (Simunek et al., 2012). Soil moisture contents were used as input parameters for the simulation of infiltration measurements. When comparing, Nash Sutcliffe efficiency value was found to be 0.87 for those comparison, which indicated a good agreement between field observation and simulated results.

Project Title: Effect of UV light on bioavailability of dissolved organic nitrogen in wastewaters

Fellow: Swati Sharma
Adviser: Dr. Halis Simsek, Agricultural and Biosystems Engineering Department, NDSU
Start Date: 03/01/2015
End Date: 02/29/2016

Presentation

Sharma, S., M.H. Ademola, H. Simsek (2015). Impact of solids retention time on wastewater derived bioavailable dissolved organic nitrogen. ASABE Annual International Meeting, July 26-29, 2015, New Orleans, LA.

Sharma, S., M.H. Ademola, H. Simsek (2015). Wastewater treatment using microalgae Chlamydomonas Reinhardtii and bacteria in a continuous flow stirred-tank reactor (CSTR). North Dakota Experimental Program to Stimulate Competitive Research (ND EPSCoR) State Conference, April 22, 2015, Fargo, ND. (Poster presentation)

Research Description

Dissolved organic nitrogen (DON) originated from anthropogenic sources including agriculture, animal wastes and wastewater treatment plants (WWTPs) has been a major environmental concern in nutrient sensitive receiving waters. Nutrient pollution in the estuaries, lakes, rivers and other water sources has caused imbalance of nutrient uptake in the aquatic ecosystems. This impairment has affected not only environmental aspects but also had negative economic and societal impacts. A need for the establishment of nutrient pollution control strategies was proposed in order to preserve and protect the aquatic systems. Eutrophication, caused by availability of excess nutrients in natural surface waters remains as a great environmental concern in water ecosystem. Nutrients in water bodies contain high concentration of nitrogen that causes excessive growth of algal and phytoplankton species. This eventually causes oxygen depletion and loss of aquatic animals.

A portion of DON is biodegradable to aquatic species while a portion of it is bioavailable after biodegradation. Biodegradable DON (BDON) is the portion of DON that is degraded by bacteria and made DON further bioavailable (ABDON) to algae leading to depletion of dissolved oxygen.

Photochemical decomposition of DON is another pathway to provide N source to algae and bacteria in aquatic system. Photodegradable DON (PDON) is a portion of DON that is decomposable by sunlight or artificial light to lower molecular weight organic compounds or inorganic nitrogen, which causes undesirable conditions in aquatic ecosystems by affecting bacterial growth, bacterial nutrient demand, bacterial biomass, and respiration rates in aqua system. BDON and ABDON after UV light irradiation called as PBDON and PABDON, respectively.

The main scope of this research is to determine the impact of UV light exposure on DON prior to using algal and/or bacterial inoculum for wastewater samples collected from a trickling filter WWTP. The specific objectives are:

- To examine the effect of UV light exposure time on photochemical degradation of DON, BDON, and ABDON.
- To determine (i) ABDON in algae + bacteria inoculated biological reactor that contains MBBR media, and (ii) PDON, PBDON, and PABDON in UV light applied samples collected biological reactor effluent.

All the samples used in this study were collected in primary effluent from the City of Fargo WWTP, which has a two-stage tricking filter process with a peak pumping capacity of 29 MGD and an average flow of 11-15 MGD. The experiments were set up to determine different UV light exposure time effect on primary effluent samples. UV light irradiance were applied on the samples in different time scale and then incubation period was applied using bacteria and/or pure cultured algae, *Chlamydomonas reinhardtii* to determine BDON, ABDON, PBDON, and PABDON. In the second part of the study, experiments were conducted in three steps. In the first step, primary wastewater samples were placed in an 8 liters reactor and seeded with bacteria. Moving bed biofilm reactor (MBBR) media added to this reactor and the reactor run in dark. In second phase, the effluent of first reactor was connected to another 8 liters of reactor and this second reactor seeded with algae + bacteria. Since algae need light sources, this reactor was run 12 hours light / dark condition. In third step of the study, UV light was applied for 6 days on the samples collected from second reactor effluents. After 6 days of light exposure, the samples were incubated using bacteria and algae + bacteria. The samples were collected daily from the reactors.

Significance of Research

Understanding the removal of DON in WWTPs has become critical due to stringent effluent discharge limits on nitrogen. A previous study conducted in Fargo WWTP expressed that UV light exposure can degrade DON to support further biodegradation using bacteria. However, the effect of UV light on bioavailable DON to algae + bacteria has not been studied in wastewater treatment processes including trickling filter process. This research will provide a comprehensive data to address nutrient contamination introduced to surface waters in ND. For the first time, pure-cultured algae and UV light interaction will be investigated to determine photo-bio availability of DON. Hence, determining DON, BDON, ABDON, PDON, PBDON, and PABDON in primary wastewater could help in understanding how to reduce effluent TDN concentration. The research can be extend collecting samples in different locations of the WWTP. The findings of this research will be presented at national and/or regional conferences and will be submitted for publication in a peer review journal. A final report containing all the information on the project including raw data will be delivered at the end of the project.

Significant Findings

UV light experiments showed that the optimal efficiency of UV irradiation in the removal of DON was observed between 8-12 days. Symbiotic combination of algae and bacteria had higher removal efficiency thereby producing higher concentration of photodegradable bioavailable DON. PDON gradually decreased on exposure of longer irradiation although no significant reduction was observed after 12 days. PABDON and PBDON increased after 21 days of incubation which shows that DON was becoming bioavailable to bacteria and algae. It was observed that effect on ammonia was minimal during the exposure to UV light. Whereas, a drastic reduction has been observed after

the UV exposed samples were incubated with bacteria only and combination of algae and bacteria. A similar trend was observed when a series of standard reagents were exposed to same experimental set up. Incubation with bacteria and algae + bacteria undergoes nitrification by complete conversion of DNH_3 to DNO_2 and DNO_3. Although, there was a minimal change in TDN after bacterial incubation, significant changes were observed in TDN between the UV exposed sample and after algae + bacteria incubation due to uptake of DNO_3 by algae and bacteria as nutrient. However, the results were not statistically significant. Further replication of the experiments is required.

Project Title: Design parameters of embankment dams in the upper midwest in potential climate change conditions

Fellow: Bahareh Shoghli
Adviser(s): Dr. Yeo Howe Lim, Civil Engineering Department, UND
Start Date: 03/01/2015
End Date: 02/29/2016

Presentation

Shoghli, B., Y.H. Lim (2015). Predictive scheme for failures of embankment dams with high overtopping potential: Case studies using remote sensing data. World Environmental & Water Resources Congress, May, 2015, Austin, TX.

Shoghli, B., Y.H. Lim (2015). Comparative study for evaluating the soil moisture in improving flood forecasting. North Dakota Experimental Program to Stimulate Competitive Research (ND EPSCoR) State Conference, April 22, 2015, Fargo, ND. (Poster presentation)

Research Description

This study identifies small and medium-sized dams in the Upper Midwest and assesses the operation and performance of associated dam appurtenances according to a series of climate change scenarios. The parameters of interest in this research are a regional factor, a hydrologic factor related to water elevation of the reservoir, and the type of dam. Regional factor, the effect of the climate change at the Midwest and Northern region of the United States is totally different from the southern region. The confidence in the projected impacts of climate change is higher for winter and spring than for summer and fall. Studies have shown that in during the winter and spring seasons, the northern area receives significantly more precipitation than the other part. The effect of the climate change is not limited to the precipitation in this region; it also has an effect on the temperature, runoff and snow melting. In regions where precipitations are expected to increase significantly under climate change conditions, the most direct impacts are in terms of the increased water elevation found in reservoirs associated with embankment dams. Investigations by researchers in the climate change area have indicated that the impact varies from one place to another. In some places, we have more extreme droughts occurrences of decreased water elevation. But in the Midwest, this change show itself as increasing the water elevation. Lim et al. (2012) modeled Devils Lake in North Dakota, which was showing increasing water elevation, under the influence of climate change factors including precipitations and temperature. More than 30 % of the embankment dam's failures in the US is caused by overtopping. The probability of the overtopping is related to the ratio of the height of the dams to the maximum elevation of the water in the reservoir. By increasing the elevation of the water, the risk of overtopping will increase. Precipitation is not the only parameter that affects the elevation of the water in the reservoir of the dams. The winds set up, sedimentation, evapotranspiration, and runoff are the parameters that also affect the elevation of the water in a reservoir. Small dams are the dams that have the height between 20 ft and 50 ft, and the reservoir capacity between 100 acre-feet and 400 acre-feet. A large number of the dams in the Midwest are small dams, and the spillways of these dams are designed with a flood peak with return periods in the order of 100- to 1000-year. This category of dam is likely to be more sensitive to the impacts of climate change. Renwick Dam in the North

Dakota was selected in the preliminary study and more in ND and the Midwest region will be investigated.

Significance of Research

Climate change can affect the dams and their performance through alterations of the hydrologic cycle. Warmer temperature accompanied by more precipitation could lead to larger snowpack and earlier spring melting of snowpack, which could increase the elevation of runoff in the basin. Conversely, lower temperatures accompanied by lesser precipitation could decrease the snowpack and delay the spring melting of the snowpack, which in turn, would lead to a decrease in runoff within the basin. Both scenarios, along with other climate-change scenarios, could alter the basin runoff.

Reservoirs filled with sedimentation are at greater risk during an earthquake because the sediment densities are greater than the displaced water and exert a greater force against the dam during an earthquake. They are also global sinks for carbon and other nutrients which are the sources of the greenhouse gases in the world. On the other hand, a sudden loss of the storage capacity of a reservoir can be caused by excessive rainfall and snow melt. Sedimentation is a much slower process but it also increases the probability of overtopping in dams, which is the leading cause of dam failure in the world

The designs of many small dams were done prior to the probable start of climate change or cycle. Some specific questions to be answered would include how the induced changes in the sedimentation rate in the basin may influence the operation of dams. How would the performance of dams be under this new climate regime? Can they operate in the way of “business as usual”? To what extent is the safety of dams being compromised under the new climate and hydrologic regimes?

Significant Findings

The objective of this study was to understand the impact of the climate change on the storage capacity of the reservoir dams. Construction of a dam leads to the creation of an artificial reservoir which normally decreases the flood peak discharge downstream of the dam. However, climate change may increase the extreme flood events generated at the upper watershed which may result in an increased probability of overtopping the dam. In the first step of this study the watershed of dams are simulated by HEC-HMS and Arc SWAT, and an evaluation was carried out to select the more capable software for the simulation of climate changes impacts on the reservoirs. The results show that for finding the effect of climate change parameter on the watershed area Arc-SWAT, which is a physical and watershed-based hydrological model, is better.

Project Title: An assessment of the influence of economic drivers of land use change on nitrate concentrations in the Red River of the North Basin

Fellow: Brent Silvis
Adviser(s): Dr. Haochi Zheng, Earth System Science & Policy Department, UND
Start Date: 03/01/2015
End Date: 02/29/2016

Presentation

Silvis, B. (2015). The Impact of policy and economic drivers of corn production on nitrogen levels of the Buffalo River subbasin, Minnesota, 2006-2014." Geological Society of America North-Central Section Meeting, May, 2015, Madison, WI.

Silvis, B., H. Zheng (2015). Policy and economic forces driving nitrate level changes in Buffalo River Subbasin, MN. North Dakota Experimental Program to Stimulate Competitive Research (ND EPSCoR) State Conference, April 22, 2015, Fargo, ND. (Poster presentation)

Research Description

The objective of this project is to test the hypothesis that changing economic conditions influence crop production and, consequently, water quality. Requisite data are obtained, including observed nitrate concentrations within the basin, historical land use and farm economic and production data and physical data such as stream discharge. From these data two models are developed using multivariate regression: an economic-land use model which identifies the relationships between crop prices and direct costs and land use, and a land use-water quality model which quantifies the influence of crop types on nitrate concentrations.

Economic scenarios, consisting of realistic changes in policies and crop prices and expenses, are developed. These scenarios are then provided to the economic-land use model to predict land use due to the conditions defined in the scenario. The modeled land use is then input to the land use-water quality model to assess how the economic scenarios influence nitrate concentrations in the surface waters of the Red River of the North Basin.

Significance of Research

The study area selected, the Red River of the North Basin, is an interesting area due to its extensive agricultural production, unique hydrological features and internationals significance.
This project provides a straightforward, transparent statistical approach to assessing land use impacts on water quality without the use of cumbersome water models. It provides a framework for discussions of the relationships of economics, land use and water quality which can be understood by a variety of stakeholders from a variety of disciplines. The study uses a larger dataset and higher resolution data than similar studies, allowing for more robust and accurate results. Finally, the study identifies many opportunities for additional research.

Significant Findings

It has been found that economic conditions do influence land use. Uniform increases in the price of major crops result in disproportional increases in areas of corn. Taxes on fertilizers tend to decrease areas of wheat to a greater extent than areas of corn. A conservation program causes a much steeper decline in soybean areas than areas of other crops.

Land use changed significantly in the Red River of the North basin from 2006 to 2014. Specifically, a large area previously planted in wheat transitioned to corn. It was found that crop type does affect the nitrate concentrations observed in a basin. Corn, canola, sunflowers and wheat had similar contributions to nitrates, while sugar beets had a much greater positive influence on nitrates. Alfalfa, dry beans and soybeans were not found to statistically contribute to nitrates. Additionally, it was found that runoff had a greater contribution to nitrate concentrations than baseflow.

As economic conditions change, so will land use and nitrate concentrations. Conservation programs and fertilizer taxes were both found to be effective methods of mitigating nitrate pollution. However, conservation programs are the more economically efficient of the two strategies.

Project Title: Holistic risk assessment of surface water contamination due to oil produced water from the Bakken formation in North Dakota

Fellow: Luisa F. Torres
Adviser(s): Dr. Eakalak Khan, Civil and Environmental Engineering Department, NDSU and Dr. Om Prakash Yadav, Industrial and Manufacturing Engineering Department, NDSU
Start Date: 03/01/2015
End Date: 02/29/2016

Publication

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.

Presentation

Torres, L., O.P. Yadav, E. Khan (2016). Risk assessment of surface water contamination due to Pb-210 in oil produced water from the Bakken, ND. 3-Minute Thesis (3MT™) Competition, February, 2016, Fargo, ND.

Torres, L., O.P. Yadav, E. Khan (2015). Risks associated with water and wastewater management in unconventional oil and gas production. Poster presented at the 2015 Water Quality and Technology Conference & Exposition, November, 2015, Salt Lake City, UT. (Poster presentation)

Research Description

The research focuses on applying different methods to perform holistic risk assessments of radioactive contaminants found in produced water from unconventional oil and gas development. Another objective of the research is to measure the social risk perceptions of different stakeholders and include the results in the risk assessments. The contaminants under study are lead 210 (Pb-210), barium (Ba), strontium (Sr), and radium 226 (Ra-226). Research on Pb-210 in produced water in ND has not been conducted despite the fact that lead is known for its harmful effects, especially on children, such as causing damage to the brain and nervous system, slowed growth and development, learning and behavior problems, and hearing and speech problems. For the assessment of Pb-210, historical data on produced water from ND was analyzed to simulate the radiation levels. With this data, a holistic risk assessment of surface water contamination due to Pb-210 was performed based on three different scenarios where produced water could impact surface water. Simulation was applied in this study by using Palisade's decision tool @Risk® and the Canadian Centre for Environmental Modelling and Chemistry (CEMC)'s Quantitative Water Air Sediment Interaction (QWASI) model. A survey was developed to capture the risk perceptions of the general public, operators, and emergency management personnel in ND and the results will be included in the quantitative risk assessment. For the assessment of Ra-226, historical data on Ba and Sr levels in produced water from The Bakken are being analyzed. Based on the correlation of these three chemicals a multivariate regression model will be developed to predict Ra-226 in ND. Similar to the study on Pb-210, a holistic risk assessment will be conducted based on scenarios

were general public and operators could be exposed to produced water with Ra-226 levels. The results from the survey are going to be included in the assessment as well. The average Ra-226 results obtained in the Pb-210 assessment will be compared with the concentration calculated in the second risk assessment, focused on Ba and Sr, to study the variability between the methods used in each study. In addition, the results could be compared with real Ra-226 levels collected in future researches.

Significance of Research

The results of this research will determine the risks of surface water contamination and the impacts on the environment and human health. In addition, the risk perception from different stakeholders in North Dakota is going to be established. Some of the contaminants found in the produced water are well known and have been extensively studied in the past but there are some which impacts are not completely understood. One example is radioactive material which is considered for this research. For the Pb-210 risk assessment, the initiating events, or situation that promote the risk of water contamination were identified. The frequency or probability of those risks to happen were assessed using qualitative and quantitative methods. Lastly, the consequences of the risks were determined focusing on the environment and human health. Similar results are expected to be obtained for the second risk assessment focused on Ba and Sr. The outcome of this thesis will give a better understanding on the importance of holistic risk assessment in the unconventional oil and gas industry by showing the potential impacts on human health and the environment. Moreover, this research will serve as a basis for future studies on produced water from unconventional oil and gas development.

Significant Findings

The research has revealed that there is a significant lack of data on produced water quality, especially radiation levels, in North Dakota. There is also concern from the general public regarding illegal dumping of radioactive material in ND which has been documented only by the media. After analyzing the ND Department of Health spills reports, the most significant scenarios where produced water is spilled involve: 1) storage tank overflow; 2) leakage from equipment, mostly pipelines; and 3) accidents related to trucks used to transport the produced water. Simulation of Pb-210 levels indicate that the average concentration after one year of produced water generation is 540 pCi/L and the concentration that remains after the chemical undergoes different process in a surface water body and drinking water treatment is 17 pCi/L or 0.63 Bq/L. This value exceed the maximum allowable level of lead in drinking water of 0.1 Bq/L established World Health Organization. After performing the characterization of the risk of each scenario under study, results show that scenarios 1 and 3 are considered low while scenario 2 is classified as medium risk. The results from the social risk perception survey are being collected for analysis. These responses will be quantified and included in the risk characterization which will deliver holistic results. The risk assessment on Ba, Sr, and Ra-226 has been initiated and data is currently being collected and analyzed.

Project Title: Effects of calcium based surface amendments on hydraulic conductivity and selected physical properties of subsurface drained sodic soils

Fellow: Anthony Walekhwa Wamono
Adviser(s): Dr. Dean D. Steele and Dr. Zhulu Lin, Agricultural and Biosystems Engineering Department, NDSU
Start Date: 03/01/2015
End Date: 02/29/2016

Presentation

Wamono, A., D. Steele, Z. Lin, T. DeSutter, X. Jia, D. Clay (2015). Effects of gypsum and sugarbeet spent-lime application on the hydraulic properties of subsurface drained saline-sodic soils. ASABE Annual International Meeting, July, 26-29, 2015, New Orleans, LA.

Research Description

The installation of tile drainage to remove excess moisture in the fall and spring poses a risk of transforming saline-sodic soils to sodic soils in the Northern Great Plains. Yet, leaching of sodic soils with low electrical conductivity water results in the swelling of the soil, dispersion of clay particles and consequently the breakdown of soil structure. Changes in soil hydraulic and physical properties ensue, such as reduced hydraulic conductivity and increased soil hardness when the soil is dry.

In this study, the cone index (CI), a measure of penetration resistance, was determined for plots at Wyndmere and Grand Forks sites in North Dakota using a hand held penetrometer. Soil water content measurements were taken augment the CI data. Statistical analyses of CI relationships with depth, moisture content, drainage state, and surface treatments were determined. A Cornell sprinkler infiltrometer was used to measure the changes in hydraulic conductivity of the plots. The effectiveness of calcium based surface amendments and cover crops under drainage and non-drainage options on improving the hydraulic and mechanical properties soil was evaluated.

Significance of Research

Maintaining productive and sustainable agriculture on poorly drained soils depends on understanding the risk of dispersion and hardsetting posed by draining saline-sodic soils. The results of this study are helping to develop guidelines and recommendations for removing excess water, thereby improving the trafficability and workability of sodic-saline soils.

Significant Findings

The experiments showed that gypsum application increased the penetration resistance of the soil during the wet conditions, reduced the drawbar power requirements and improved the movement of the water through the soil matric in comparison to spent lime. The improvement in infiltration was limited to the soil matrix with water at 2 cm tension, the final infiltration including both matrix flow and flow the larger macro-pores was not affected by the surface treatments. There were no

significant differences for penetration resistance, drawbar power, or infiltration in the drainage treatments (undrained and drained plots). However, the effects of drainage were evident in the combined effects of drainage and surface amendments, where drainage was observed to augment the impact of surface amendments. The improvements in the penetration resistance was observed in the 15 to 30-cm layer, which was beyond the depth of incorporation of the surface amendment (10 to 15 cm). For many farmers, drainage enables early planting and adding ameliorants will safeguard further sodification of their fields. Lowering draft as a result is an added incentive which also needs to be captured in a cost-benefit analysis and the present study provides a useful starting point for such analyses.