

**South Dakota Water Research Institute
Annual Technical Report
FY 2007**

Introduction

South Dakota's Water Resources Research Institutes program is administered through the College of Agricultural and Biological Sciences at South Dakota State University (SDSU). Dr. Van Kelley has been the Director since August 1, 2000. Dr. Kelley is also the Department Head of the Agricultural and Biolsystems Engineering Department. The annual base grant from the United States Geological Survey (USGS) and a legislative appropriation of \$103,270 form the core of the SDWRRI budget. The core budget is supplemented by research grants from a variety of funding agencies as well as private organizations interested in specific water issues.

The mission of the South Dakota Water Resources Institute is to address the current and future water needs of people, agriculture, and industry through research, education, and service. This report is a summary of activities conducted during Fiscal Year 2007 to accomplish this important mission.

Research Program Introduction

Research

Water is one of the most important resources in South Dakota. Together with the state's largest industry, agriculture, it will play an important role in the economic future of the state. Enhancement of the agricultural industry and allied industries, the industrial base and, therefore, the economy of South Dakota all depend on compatible development of our water resources.

During 2007, the South Dakota Water Resources Institute (SD WRI) used its 104B Grant Program funds to conduct research of local, state, regional, and national importance addressing a variety of water problems in the state. The Advisory Committee reviews grant applications and recommends projects for funding that address research priorities, have a good chance of success, and increase our scientific knowledge. Manure management and its impact on water quality, drinking water quality, bio treatment for the removal of uranium from water, vegetative treatment for feedlot runoff, and conservation of irrigation water were emphasized in fiscal year 2007. As the livestock industry grows and develops in South Dakota, manure management and its impact on water quality will continue to be a priority for research.

Animal feeding operations are a major industry in South Dakota and across the Midwest. The practice of applying manure to frozen or snow covered ground varies from state to state in the Midwest because of variation in state regulations and interpretation of the risk of this practice by producers receiving conservation funding from the USDA–NRCS. Substantial data and research is needed in evaluating the potential water quality impacts (relative to standard practices) and assessing the risk of occurrence of weather conditions that can lead to increased risk from applying manure on frozen or snow covered ground. This project seeks to evaluate this practice by assessing the frequency (risk) of climatic conditions expected to lead to excessive runoff from winter conditions and the laboratory comparison of winter applications to typical spring/summer/fall applications.

With growth in the South Dakota economy, increasing demands have been placed on water supplies. Irrigation is a major use of water in South Dakota and wise use of irrigation water is important if other water needs like ethanol production are to be met in the future. In FY2007, research was supported to develop methods to conserve irrigation water by water management, water conservation, automated irrigation scheduling, and crop models. This technology is expected not only to conserve water but also reduce pumping costs, increase crop production, and minimize leaching of nitrates into groundwater supplies.

In the United States, past activities associated with mining, extraction, and processing of uranium (U) for nuclear fuel and weapons have generated substantial quantities of toxic waste materials contaminated with U. U is a known carcinogen, and the high solubility of its hexavalent form can result in U transport to sensitive receptors such as drinking water sources. Potential methods of treating U contamination include: natural dissimilatory metal reducing bacteria (DMRB) and sulfate reducing bacteria (SRB). In addition, in the presence of Fe–bearing minerals, biogenic sulfide can react to form iron sulfides, which can help maintain reducing environments important to uraninite stability.

Some areas of South Dakota have elevated levels of arsenic, cadmium, and lead in drinking water supplies. Removal of these metals especially by small rural water system operators is a challenge. A research project to improve the efficiency of limestone–based materials for metal removal from drinking water was supported in FY2007. This is part of the effort to develop low–cost remediation technology that can be used to help small or rural water supply systems meet regulations.

Nutrient and sediment loads from animal feeding operations (AFOs) can negatively impact the quality of surface waters and groundwaters. A research project to evaluate the technical and financial feasibility of vegetated treatment areas (VTAs) as a non-basin alternative for reducing nutrient and sediment loads from AFOs having less than 1,000 animal units was supported. Five AFOs in different areas of South Dakota were established.

Microbial Indices of Soils and Water Associated with Vegetated Treatment Areas (VTAs) from Five Animal Feeding Operations (AFOs) in South Dakota

Basic Information

Title:	Microbial Indices of Soils and Water Associated with Vegetated Treatment Areas (VTAs) from Five Animal Feeding Operations (AFOs) in South Dakota
Project Number:	2006SD74B
Start Date:	3/1/2006
End Date:	2/28/2009
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Water Quality, Surface Water, Acid Deposition
Descriptors:	
Principal Investigators:	Bruce Bleakley, Todd P. Trooien

Publication

1. Bleakley, B.H. 2007. Microbial indices of soil and water. South Dakota Water Resources Institute Water News. January 2007, volume 3, number 1.

Progress Report

State Water Resources Institute Program (SWRIP)

March 1, 2007, to February 29, 2008

Title: Microbial indices of soils and water associated with vegetated treatment areas (VTAs) from five animal feeding operations (AFOs) in South Dakota

Investigators: Dr. Bruce Bleakley, South Dakota State University
Dr. Todd Trooien, South Dakota State University

Introduction:

Nutrient and sediment loads from animal feeding operations (AFOs) can reduce the quality of surface waters and groundwaters. Basin technologies can help alleviate some of these problems, but they can be costly, and cause odor problems. The potential for development and implementation of alternative non-basin technologies interests a variety of stakeholder groups. An EPA funded grant, "Evaluating the Performance of Vegetated Treatment Areas," (Dr. Todd Trooien, P.I.), seeks to evaluate the technical and financial feasibility of vegetated treatment areas (VTAs) as a non-basin alternative for reducing nutrient and sediment loads from AFOs having less than 1,000 animal units. For this EPA grant, each of five AFOs in different areas of South Dakota have had or will have VTAs established. Performance of each VTA is being measured by sampling inflows and outflows from vegetated areas. The samples are being analyzed for nutrients (N and P), salts, sediment, and numbers of fecal coliform bacteria. Data from these measurements will allow calculation of water and salt balances, loss or gain of nutrients, removal of sediment, and fecal coliform numbers. Data will be entered in a basin model to simulate basin performance, that will be compared to measured VTA performance. Samples have been obtained from 2005 to 2008. For the EPA project, only numbers of fecal coliform bacteria are being measured. Other aspects of the microbiology of the inflow and outflow areas associated with the VTAs are not addressed, and are the focus of this 104b proposal.

Project Information:

Information Transfer Program: Some of the information presented here was also presented at a stakeholders meeting tied to the Ag United meeting for the Vegetative Treatments Systems project (sponsored by EPA via DENR) held on December 7, 2006 at the Sioux Falls Ramkota Inn; and at a Stakeholders Meeting on the SDSU campus on February 20, 2008; and at a field day held at the Howard site in 2007.. Data from this project will continue to be presented at such stakeholder meetings; and at field days at one or more of the VTA sites of the study.

Problem:

Nutrient and sediment loads from animal feeding operations (AFOs) can negatively impact the quality of surface waters and groundwaters. One accepted way to

reduce nutrient and sediment loads from AFOs is by use of basin technologies, which are effective but can be costly, and lead to air quality problems due to unpleasant odors. The potential for development and implementation of alternative non-basin technologies interests a variety of groups, including the South Dakota Cattlemen's Association, South Dakota Farm Bureau, South Dakota Association of Conservation Districts, South Dakota State University, South Dakota Department of Agriculture, Natural Resources Conservation Service, South Dakota DENR, and cattle producers. The Iowa Cattlemen's Association (ICA) is also interested.

An EPA funded grant, "Evaluating the Performance of Vegetated Treatment Areas," (Dr. Todd Trooien, P.I.), has been underway since 2005 to the present. Its goal is evaluation of the technical and financial feasibility of vegetated treatment areas (VTAs) as a non-basin alternative for reducing nutrient and sediment loads from AFOs having less than 1,000 animal units. Each of five AFOs in different areas of South Dakota have had or will have VTAs established. Performance of each VTA will be measured by sampling inflows and outflows from vegetated areas. The samples are being analyzed for nutrients (N and P), salts, sediment, and numbers of fecal coliform bacteria. Data from these measurements will allow calculation of water and salt balances, loss or gain of nutrients, removal of sediment, and fecal coliform numbers. Data will be entered in a basin model to simulate basin performance, that will be compared to measured VTA performance.

For the EPA project, counts of *E. coli* before and after each VTA are the only measure being taken of bacterial effects on water quality in pre- and post-VTA areas. Other microbial measures affecting water quality would also be valuable, such as detecting presence or absence of toxigenic *E. coli*, such as *E. coli* O157:H7; and numbers of non-toxicogenic *E. coli* in pre- and post-VTA areas at each site, to better assess whether water quality in post VTA areas is better (has lower numbers of these bacteria) than in pre-VTA areas. Also, since microbial activity can influence physical and chemical parameters of soil and water, such as whether aerobic or anaerobic processes are occurring, other measures of microbial activity would be valuable for both pre-VTA and post-VTA areas at each site, to further assess water quality in these areas. The 104b project described here is providing a more detailed and broader understanding of some microbiological issues relating to this waste management system.

Research Objectives:

For the EPA project described above, counts of *E. coli* before and after each VTA are the only measure being taken of bacterial effects on water quality in pre- and post-VTA areas. Other microbial measures affecting water quality would also be valuable, such as detecting presence or absence of toxigenic *E. coli*, such as *E. coli* O157:H7; and total *E. coli* other than *E. coli* O157:H7 in pre- and post-VTA areas at each site, to better assess whether water quality in post VTA areas is better (has lower numbers of these bacteria) than in pre-VTA areas. Also, since microbial activity can influence physical and chemical parameters of soil and water, such as whether aerobic or anaerobic processes are occurring, other measures of microbial activity would be valuable for both pre-VTA and post-VTA areas at each site, to further assess water quality in these areas.

Differences in the microbiology of soils in the inflow and outflow areas associated with VTAs is being assayed by measuring the following microbial indices: (a) Soil respiration; (b) oxidation/reduction potential; (c) heterotrophic microbial activity; (d) soil bacterial diversity; (e) numbers of total culturable *E. coli* in water ; and (f) presence or absence of culturable pathogenic *E. coli* O157:H7. Data for these microbial indices will be added to the data sets from the EPA project, to get a better idea of the number and activity of microbes in soils associated with inflow and outflow areas.

Methodology:

Soil respiration is being measured in the field with a portable soil respirometer. Both plant root respiration and microbial respiration can contribute to the values obtained (Alef, 1995a; Beck, 1996). Oxidation/reduction potential of wet soils will be assayed in the field with a portable meter fitted with an oxidation/reduction electrode (Zausig, 1995). Heterotrophic microbial activity is being evaluated by assaying ability of soil samples to hydrolyze fluorescein diacetate (Alef, 1995b). Soil bacterial diversity will be assayed in two ways: (1) by use of Biolog EcoPlates that assay the ability of a soil microbial community to utilize different carbon sources (Insam and Goberna, 2004) ; and (2) by molecular methods, using polymerase chain reaction (PCR) and denaturing gradient gel electrophoresis (DGGE) (Hastings, 1999; Baker and Harayama, 2004). We are evaluating the numbers of *E. coli* of humans and animals in both inflow and outflow water. Water samples from the Howard site have been analyzed by counting coliforms on mfc agar, then picking these colonies over onto Chromagar plates that are more specific in identifying colonies of *E. coli*. A serologic test was used to determine if water samples contained *E. coli* O157:H7.

Principal Findings

i) Assessing the redox state of the soil and/or water in inflow versus outflow areas: Because of dry conditions throughout the state for most of 2006 including at the Howard site, redox potential was not measured at Howard or elsewhere for that year. At the end of 2007, initial readings were taken at Howard in the fall when standing water was present at several of the sampling areas for this site. Using a portable redox electrode, redox values were found to be negative at most of the water saturated sites, with negative values ranging from -120 millivolts to -250 millivolts. These negative readings indicate that the sample sites were largely or entirely anaerobic, so that processes such as fermentation, sulfate reduction, and denitrification were likely occurring. In June of 2008, soon after major rainfall events, redox electrode readings were again taken in Howard when the soil was moist but not water saturated. Readings at all sample sites were positive, ranging from 124 to 280 millivolts, indicating that the soils were largely aerobic and conducive to aerobic microbial processes and plant root metabolism. Engineering changes occurred in the layout of the drainage pipes at the Howard site between 2007 and 2008 to further spread flow of water from the feedlot over the landscape, and may be promoting more positive redox values/aerobic conditions over the entire landscape, even during wet periods. Redox readings will continue to be taken at Howard and the other sites in 2008, especially during wet periods (since redox measurements cannot meaningfully be taken on dry soils).

The hypothesis being tested is that redox values will be more negative in areas having largest amounts of organic load from the AFOs; where microbial respiration will have depleted oxygen gas concentration and led to anaerobiosis. The data set obtained over the next year will help decide whether this hypothesis is supported or not.

ii) Assessing the activity of microorganisms in soil and/or water in inflow versus outflow areas by use of a portable soil respiration monitor (for drier soils only): Carbon dioxide measurements were made at the Howard site in pre VTA and post VTA areas from late summer to fall of 2006. Preliminary analysis of respiration data (not yet statistically analyzed) suggests that there were not significant differences in CO₂ production between pre VTA and post VTA areas on the dates sampled, possibly because the respiration of grass roots was so dominant and equivalent in both areas. It is clear from data obtained to date that soil temperature is a major determinant of soil respiration, more so than moisture. Soil temperatures around 21° C gave respiration values (g CO₂/m²/hour) ranging from 2 to 6; while soil temperatures around 8° C gave values that were three to eight times lower.

During 2007, soil respiration readings taken in summer and fall, (after the soil had dried enough to be assayed). Values were no higher than 2006, especially in the summer. How soil respiration values correlate to FDA hydrolysis measures, and to soil temperature and moisture, needs to be examined.

We are testing the hypothesis that respiration will be higher in inflow areas compared to outflow areas, due to greater organic matter load stimulating microbial respiration in the inflow areas than in the outflow areas. Data obtained to date from the Howard do not clearly support this, but work over the next year including data from the other VTA study sites will help decide whether the hypothesis is supported.

iii) Assessing the heterotrophic activity of microorganisms in soil and/or water in inflow versus outflow areas by use of a spectrophotometric assay of fluorescein diacetate (FDA) hydrolysis in inflow vs. outflow soil and/or water: Soil samples from pre VTA and post VTA areas of the Howard site collected from 2006 and 2007 have been analyzed for FDA activity, (with some samples yet to be processed; but data have not yet been statistically analyzed. It is clear that different sites at Howard have different FDA hydrolysis values over time, and there are differences between sites. How these values correlate to values of soil respiration, temperature, and soil moisture needs to be examined.

We hypothesize that FDA hydrolysis will be greater in inflow areas than outflow areas, since higher amounts of organic matter in inflow areas should stimulate more microbial activity than in outflow areas. Data obtained to date from Howard do not clearly support this, but work over the next year including data from the other VTA study sites will help decide whether this hypothesis is supported.

iv) Assessing soil bacterial diversity in inflow versus outflow soil and water by means of denaturing gradient gel electrophoresis (DGGE) to compare number of gel bands obtained from samples from inflow versus outflow soil and water, employing 16S ribosomal DNA primers and polymerase chain reaction (PCR) methodology: This is a molecular method that will be able to assess both the culturable and non-culturable bacteria in soil samples. Soil samples from pre VTA and post VTA areas of the Howard site will be analyzed using DGGE. This analysis will be completed in the next year. We

hypothesize that bacterial diversity will be greater in inflow versus outflow areas, due to greater amounts and types of organic matter available in the inflow areas; and to more likely frequent periodic aerobic/anaerobic transitions in the inflow areas, versus the outflow areas.

v) Assessing soil bacterial diversity in inflow versus outflow soil and water by means of carbon source utilization profiles of soil microbial communities in the inflow and outflow areas using Biolog EcoPlates: Soil samples from pre VTA and post VTA areas of the Howard site have been/are being analyzed using Biolog plates, but have not yet been statistically analyzed. We hypothesize that bacterial diversity will be greater in inflow versus outflow areas, due to greater amounts and types of organic matter available in the inflow areas; and to more likely frequent periodic aerobic/anaerobic transitions in the inflow areas, versus the outflow areas.

vi) Evaluating the numbers of specific fecal coliforms and/or potential pathogens of humans and animals in both inflow and outflow soil and water by use of several agar media that are selective and differential for specific bacterial types: Water samples from the Howard site have been analyzed by counting coliforms on mfc agar, with numbers ranging from 10^4 to 10^5 CFU coliforms/ml in the pre-VTA and post-VTA samples. Picking these colonies over onto Chromagar plates has shown for both 2006 and 2007 samples that most (in excess of 50%) but not all of the initial isolated colonies were *E. coli* in the pre-VTA and post-VTA areas. In 2006 water samples from the river in the area behind the post-VTA area, fecal coliforms were found in lower numbers (10^2 CFU coliforms/ml) than in pre and post VTA areas, with from 20% to 70% of those in the river verified as *E. coli*. For 2006 samples we detected presence of *E. coli* O157:H7 in pre-VTA and post-VTA water samples, but not in river samples situated after the post-VTA area. This indicates that the VTA is effectively removing *E. coli* strains of the greatest health concern before they reach the river.

For Howard in 2007, with water samples from the river in the area behind the post-VTA area, fecal coliforms were found in lower numbers than in pre-VTA and post VTA areas, but for some sampling dates the numbers in the river were only one log less than in the post VTA area. For 2007 samples we detected presence of *E. coli* O157:H7 in pre-VTA and post-VTA water samples, but not in river samples situated after the post-VTA area, again indicating that the VTA is effectively removing *E. coli* strains of the greatest health concern before they reach the river. However, there were times where cattle were grazing beside the river, so that numbers of *E. coli* in the river cannot be totally tied to the VTA but may instead originate from these grazing cattle near the river bank.

Significance

Management issues that could be impacted by results of the study include management of undesirable odors affiliated with the AFOs; extent of anaerobic versus aerobic microbial processes in inflow versus outflow areas; ability of the VTAs to filter out specific pathogenic bacteria such as *Escherichia coli* O157:H7 ; amount of CO₂ gas produced from soil in pre-VTA versus post-VTA areas; and overall heterotrophic microbial activity and microbial community diversity in soil and water in pre-VTA versus post-VTA areas as a measure of the ability of the VTA in removing organic compounds from the AFO inflow. Results could influence future management decisions

for AFOs making use of VTAs; and afford information to better understand how to manage microbial populations in the soils affiliated with the VTAs to achieve desirable air and water quality in these areas.

References Cited:

Alef, K. 1995a. Soil respiration, pp. 214-219. *In* K. Alef and P. Nannipieri (eds.), *Methods in applied soil microbiology and biochemistry*. Academic Press, Inc., San Diego, CA.

Alef, K. 1995b. Estimation of the hydrolysis of fluorescein diacetate, pp. 232-233. *In* K. Alef and P. Nannipieri (eds.), *Methods in applied soil microbiology and biochemistry*. Academic Press, Inc., San Diego, CA.

Baker, P.W., and S. Harayama. 2004. An analysis of microorganisms in environments using denaturing gradient gel electrophoresis, pp. 323-338. *In* J.F.T. Spencer and A.L. Ragout de Spencer (eds.), *Methods in biotechnology*, vol. 16: *Environmental microbiology: methods and protocols*. Humana Press, Totowa, New Jersey.

Beck, T. 1996. Soil respiration by infrared gas analysis, pp. 98-102. *In* F. Schinner, R. Ohlinger, E. Kandeler, and R. Margesin (eds.), *Methods in soil biology*. Springer-Verlag, Berlin, Germany.

Hastings, R. 1999. Application of denaturing gradient gel electrophoresis to microbial ecology, pp. 175-186. *In* C. Edwards, (ed.), *Methods in biotechnology*, vol. 12: *Environmental monitoring of bacteria*. Humana Press, Totowa, New Jersey.

Insam, H., and M. Goberna. 2004. Use of Biolog for the community level physiological profiling (CLPP) of environmental samples. Chapter 4.01; pp. 853-860. *In* G.A. Kowalchuk, F.J. de Bruijn, I.M. Head, A.D.L. Akkermans, and J.D. van Elsas (eds.), *Molecular microbial ecology manual*, second edition-volume 2. Kluwer Academic Publishers, Dordrecht, the Netherlands.

Zausig, J. 1995. Redox potential measurement, pp. 274-276. *In* K. Alef and P. Nannipieri (eds.), *Methods in applied soil microbiology and biochemistry*. Academic Press, Inc., San Diego, CA.

Leaching Tests for Encapsulation of Waste after Arsenic Removal from Drinking Water

Basic Information

Title:	Leaching Tests for Encapsulation of Waste after Arsenic Removal from Drinking Water
Project Number:	2007SD101B
Start Date:	3/1/2007
End Date:	2/28/2009
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Treatment, None, None
Descriptors:	
Principal Investigators:	Arden D Davis, David J. Dixon, Marion Hansen

Publication

1. Davis, A.D., Webb, C.J., Dixon, D.J., Sorensen, J.L., and Dawadi, S., 2007, Arsenic removal from drinking water by limestone-based material: *Mining Engineering*, v. 59, no. 2, p. 71–74.
2. Webb, C.J., Davis, A.D., Dixon, D.J., Sorensen, J.L., Berryman, G., and Williamson, T.E., Arsenic remediation of drinking water using limestone: characterization of limestone and dolomite: Submitted for publication, *Environmental Science and Technology*.
3. Sorensen, J.L., Davis, A.D., Dixon, D.J., and Hocking, C.M., 2007, Further testing of limestone-based material for arsenic removal from small water systems: Presented at 2007 Western South Dakota Hydrology Conference, April 19, 2007, Rapid City, South Dakota.
4. Chintalapati, P., 2008, Leaching and compressive strength tests of limestone waste after arsenic removal from drinking water: M.S. thesis, South Dakota School of Mines and Technology, Rapid City, South Dakota.
5. Process and apparatus to reduce the amounts of arsenic in water: Dr. Cathleen J. Webb, Dr. Arden D. Davis, and Dr. David J. Dixon; U.S. Patent Application Serial No. 10/861,586; patent pending. Continuation-in-part reviewed in 2007.

Progress Report

State Water Resources Institute Program (SWRIP)

March 1, 2007, to February 29, 2008

Title: Leaching Tests for Encapsulation of Limestone Waste after Arsenic Removal from Drinking Water

Investigators: Dr. Arden D. Davis, S.D. School of Mines and Technology
Dr. David J. Dixon, S.D. School of Mines and Technology
Dr. M.R. Hansen, S.D. School of Mines and Technology

Introduction:

This project investigated encapsulation of limestone waste product in concrete after removal of arsenic from water, and focused on leaching and compressive strength tests of the concrete. The tests could help demonstrate the potential for reuse of the waste material, thereby decreasing overall costs of limestone-based technology. The researchers used limestone as the arsenic-removal medium. In laboratory tests, arsenic-contaminated water contacted the material until measurable amounts of arsenic were adsorbed on the limestone and the arsenic concentration of the water was reduced. The limestone waste material then was removed, combined with concrete mortar, and encapsulated in a concrete cube for compressive strength tests and for leaching tests to determine whether encapsulation of waste product in concrete is a viable reuse. The Toxicity Characteristic Leaching Procedure (TCLP) test was used to determine the amount of leaching of arsenic. The research could give limestone-based technology a distinct advantage for use in small rural water systems, through recycling of the waste product.

Project Information:

Problem

Limestone-based technology for arsenic removal from water is an innovative and promising method. The technology offers the potential for low-cost disposal of waste product after arsenic removal, either in an ordinary landfill or by encapsulation in concrete. Research by the principal investigators has shown that the waste product from the limestone-based technology passes the Toxicity Characteristic Leaching Procedure (TCLP) test. Disposal of arsenic-enriched waste is critical for commercial viability of removal technologies. Low-cost disposal of waste in an ordinary landfill gives the method an advantage that could help communities meet the new maximum contaminant level for arsenic. The ability to reuse the waste material in concrete would add a significant economic benefit, reducing overall costs. Other methods of arsenic removal,

such as iron-based material, suffer from the disadvantage of higher disposal costs because of the potential for leaching of arsenic from the waste product.

Arsenic is a persistent, bio-accumulative toxin. The maximum contaminant level for arsenic, formerly 50 parts per billion (ppb), was lowered to 10 ppb in 2006 because of links to cancer. Lowering of the standard will cause economic pressures for rural communities with high levels of arsenic in their drinking water supplies. Current removal technologies are expensive and their implementation will cause economic pressures for rural communities.

Objectives

The objectives of this work were to:

- 1) Determine adsorption of arsenic in tests using limestone-based material as the treatment medium and water with arsenic concentrations of approximately 50 parts per billion.
- 2) Remove the limestone waste material and combine the product in concrete mortar. Prepare concrete cubes with material from each leaching column, using the concrete mortar and waste material from the column.
- 3) Obtain samples from the concrete cubes and conduct Toxicity Characteristic Leaching Procedure (TCLP) tests.
- 4) Analyze TCLP test results and determine the suitability of encapsulating the waste material as concrete in structural or non-structural works.
- 5) Conduct compressive strength tests on the concrete cubes to determine if the arsenic adversely affected the strength of the concrete.

The research presented in this proposal will focus on improving the economic advantages of disposal of limestone-based material by encapsulating the waste product in concrete. Overall goals include future application as a pilot study at a wellhead with naturally occurring arsenic contamination, and commercial viability of the technology.

The TCLP tests in this work were designed to determine the mobility of contaminants in wastes. Infiltrating water and other liquids that come into contact with the waste can potentially leach toxins from the material. The U.S. Environmental Protection Agency's maximum permissible concentration of arsenic for the TCLP test is five parts per million (ppm). Previous work by the researchers has shown that waste product from limestone-based material, after arsenic removal, is considered benign and suitable for disposal in a landfill. Testing is needed for encapsulated waste in concrete, however. The proposed research will help demonstrate the viability of this approach.

Methods

A solution of water with a starting arsenic concentration of approximately 50 parts per billion (ppb) was prepared. The researchers used limestone-based material from a quarry in the Minnekahta Limestone. Based on X-ray diffraction analysis, Minnekahta Limestone is composed of about 95 percent calcite, 4 percent quartz, and 1 percent microcline. In laboratory tests, arsenic-contaminated water was brought into contact with

the limestone until it had adsorbed a significant amount of arsenic from the water. Mass-balance calculations from the influent and effluent solutions were used to determine the amount of arsenic adsorbed on the limestone. The waste material then was removed, combined with concrete mortar and encapsulated in concrete cubes for later TCLP tests to determine whether encapsulation of waste product in concrete is a viable reuse. Compressive strength tests also were conducted on the concrete cubes. Laboratory facilities at South Dakota School of Mines and Technology were used in the work.

Tasks achieved during this research were: 1) a review of related published literature was completed, 2) a summary of the properties of arsenic, carbonates, adsorption theory, and concrete testing was completed to provide technical background for the research, 3) the waste-disposal properties of other innovative arsenic technologies in comparison to limestone-based arsenic removal were summarized, 4) solutions with starting arsenic concentrations of approximately 50 parts per billion were prepared, 5) the solutions were brought into contact with crushed Minnekahta Limestone to adsorb arsenic, 6) mass-balance calculations were used to determine the mass of arsenic adsorbed on the limestone, 7) concrete cubes were prepared with the limestone waste as the mortar, 8) compressive strength tests were conducted on the concrete cubes, and 9) Toxicity Characteristic Leaching Procedure (TCLP) tests were completed on crushed material from the concrete cubes.

The proposed mechanism for the removal of arsenic by limestone is the adsorption/precipitation of hydrated calcium arsenates, $\text{Ca}_3(\text{AsO}_4)_2 \cdot x\text{H}_2\text{O}$, onto the heterogeneous surface of the limestone. The solubility product of calcium arsenate, $\text{Ca}_3(\text{AsO}_4)_2$, is 6.8×10^{-19} . The removal of arsenic, and the subsequent stability of the waste product, is facilitated by the alkaline surface pH of the limestone (pH 9-10).

Principal Findings

Following ASTM standards, concrete cubes made with encapsulated limestone waste were tested. Two cubes were tested on day 1, day 3, and day 7, and three cubes were tested on day 28. Averages for the strengths, rounded to the nearest tenth, were calculated and plotted as shown in Figure 1. The averages of cubes tested for compressive strength were: for C1 and C2 (combined), 2700 psi, 4813 psi, 5163 psi, and 5125 psi; and for C3 and C4 (combined), 2288 psi, 4025 psi, 5163 psi, and 5383 psi. As mentioned earlier, the combined sample of C3 and C4 had a greater amount of arsenic than the combined sample of C1 and C2. Although the strength of cubes for C3 and C4 was less than C1 and C2 on day 1 and day 3, they were the same on day 7. On day 28, the average of compressive strengths was greater for C3 and C4 and less for C1 and C2. However, the differences were small. Tables 1 and 2 show the results of compressive strength tests. Figure 2 shows a comparison of compressive strengths of the concrete cubes prepared with arsenic, and the control cubes prepared with untreated limestone.

Table 1. Compressive strengths of combined C1 and C2 specimens.

Age (days)	Load (lbs)	Compressive Strength (psi)
1	11200	2800
1	10400	2600
3	19000	4750
3	19500	4875
7	20400	5100
7	20900	5225
28	19000	4750
28	19800	4950
28	22700	5675

Table 2. Compressive strengths of combined C3 and C4 specimens.

Age (days)	Load (lbs)	Compressive Strength (psi)
1	9100	2275
1	9200	2300
3	16000	4000
3	16200	4050
7	20000	5000
7	21300	5325
28	22200	5550
28	19300	4825
28	23100	5775

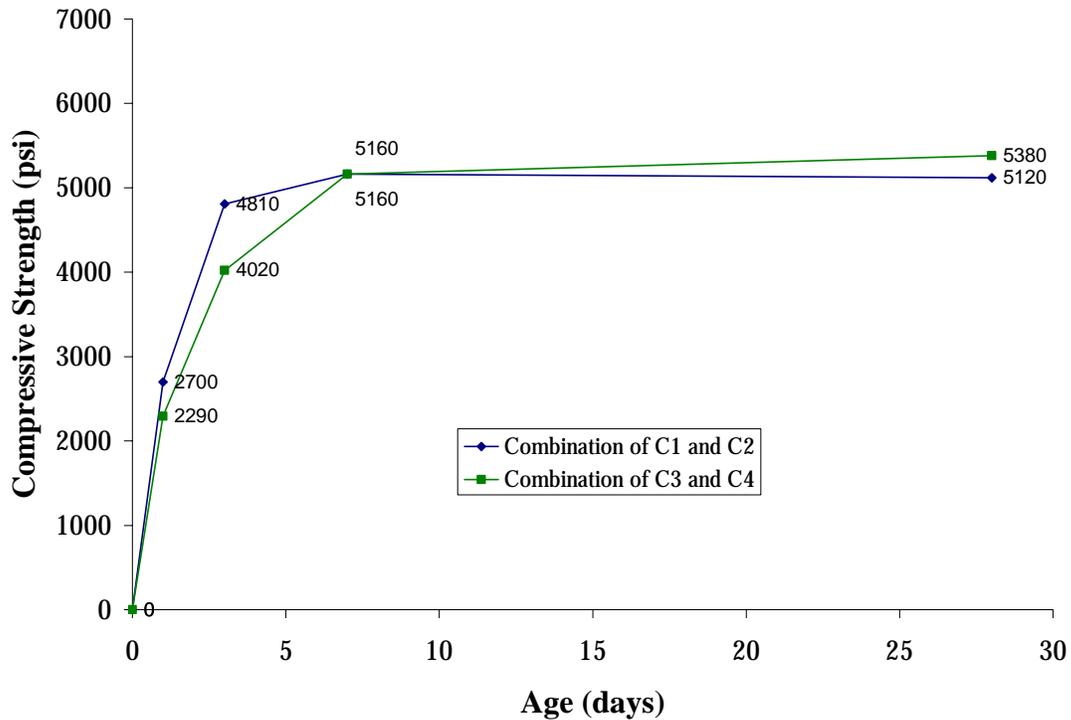


Figure 1. Compressive strengths of cubes prepared by encapsulating arsenic-enriched limestone with average of two 2 in. x 2 in. x 2 in. cubes at 1, 3, and 7 days, and average of 3 cubes at 28 days.

Both the combinations of encapsulated limestone showed low strengths on the 1st day of the test compared to the control test strength values, whereas on the 3rd day, the average strength combined sample of C1 and C2 was greater than the control test sample, and combined sample C3 and C4 was less. Both of them were greater than the average compressive strength of the control sample on day 7. Possible explanations for this behavior are either because of physical bonding established among the materials or some unknown chemical reactions that might have hampered the strength at the beginning but had less effect as time passed. The average compressive strength of concrete cubes of combined C1 and C2, tested on the 28th day, indicated a slight decrease in the strength compared to the 7th day, but they were essentially similar. These minor variations are expected in strength testing. The results indicate that the encapsulated contaminant had no appreciable effect on the strength.

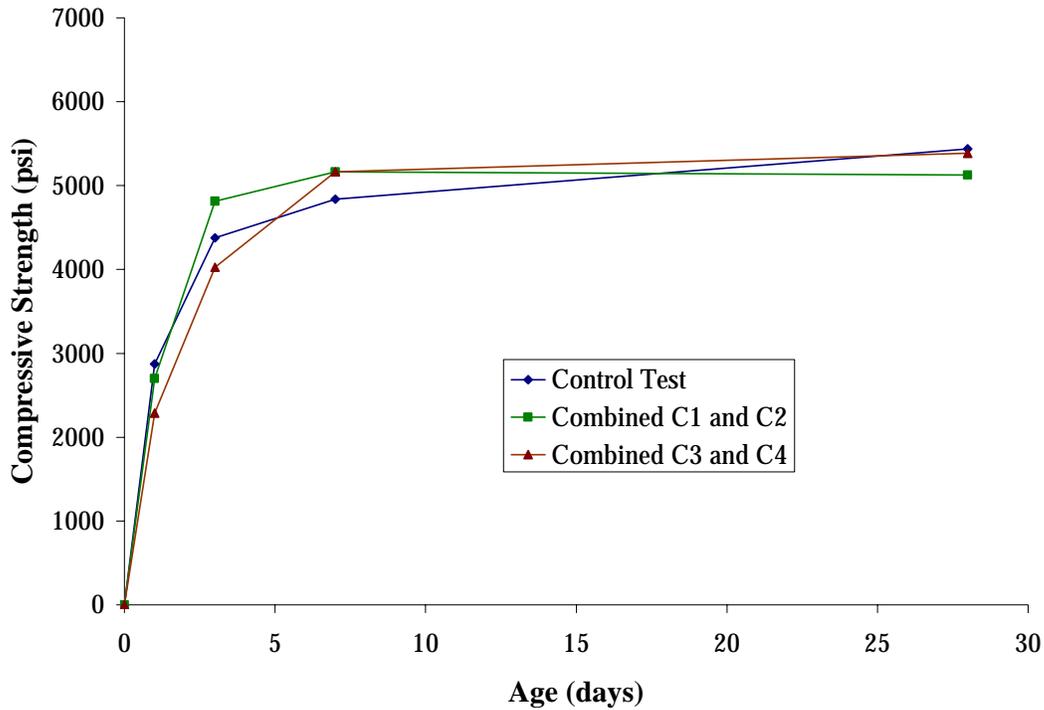


Figure 2. Comparison of average compressive strengths of concrete mortar cubes prepared through encapsulation of untreated and treated limestone.

The TCLP test results indicate that the leaching of arsenic was less than 0.05 mg/L from the concrete cubes that were analyzed by MidContinent Testing Laboratories, Inc., Rapid City, South Dakota. As mentioned earlier, the U.S. EPA's leaching limit for the disposal of arsenic in a landfill is 5 mg/L. TCLP tests were conducted on all the specimens (i.e., the concrete cubes that were tested for compressive strength at 1, 3, 7, and 28 days) for any leaching of arsenic. The results were less than 1/100 of the U.S. EPA standard. A summary of the test results is listed in Table 3.

Table 3. Results of the TCLP tests.

Sample Name	Arsenic - TCLP (mg/L)
C-1,2 D-1,2	<0.050
C-1,2 D-3,4	<0.050
C-1,2 D-7,6	<0.050
C-1,2 D-28,7	<0.050
C-3,4 D-1,2	<0.050
C-3,4 D-3,3	<0.050
C-3,4 D-7,6	<0.050
C-3,4 D-28,9	<0.050

Conclusions and Significance

The following preliminary conclusions can be drawn from this work to date.

- From the experimental data and results, it appears that the strength of concrete mortar cubes was not affected by encapsulation of limestone waste. In fact, strengths were nearly the same as in the control test.
- Because leaching of arsenic was far less than the U.S. EPA standard, as determined by the TCLP tests, encapsulation of waste limestone in concrete has potential as an option for recycling of the waste material.
- Recycling of the limestone waste could help reduce disposal costs of the limestone-based arsenic removal method.

Related work involved column experiments and engineering scale-up studies for Keystone City Well No. 4 (shown below on Figure 3).



Figure 3. Keystone City Well No. 4.

Information Transfer Program: A field demonstration project was set up for arsenic removal using ground water at a well in Keystone, South Dakota. Well water was used on-site, and water samples also were transported to a laboratory at South Dakota School of Mines and Technology.

Permeable Reactive Bio–Barriers for Uranium Removal: Role of Iron Minerals on Uranium Fate and Transport

Basic Information

Title:	Permeable Reactive Bio–Barriers for Uranium Removal: Role of Iron Minerals on Uranium Fate and Transport
Project Number:	2007SD104B
Start Date:	3/1/2007
End Date:	2/28/2009
Funding Source:	104B
Congressional District:	First
Research Category:	Ground–water Flow and Transport
Focus Category:	Radioactive Substances, Acid Deposition, Treatment
Descriptors:	
Principal Investigators:	Rajesh Kumar Sani, Sookie S Bang, David J. Dixon

Publication

1. Sani RK, Peyton BM, Ginn TM, Spycher NF, and Dohnalkova A. 2008. Subsurface uranium fate and transport: Biogeochemical functions of nanocrystalline uraninite oxidation by iron minerals. Platform presentation at the Western South Dakota Hydrology Conference, April 17, Rapid City, SD.
2. Sani RK, Peyton BM, Ginn TM, Spycher NF, and Dohnalkova A. 2008. Subsurface uranium fate and transport: Biogeochemical functions of nanocrystalline uraninite oxidation by iron minerals. Platform presentation at the 20th Annual Environmental and Ground Water Quality Conference, March 26 &27, Pierre, SD.
3. Rastogi G, Sani R, Keegan N, Stetler L, and Menkhaus T. 2008. Bacterial diversity associated with abandoned mines in South Dakota. Platform presentation at the Western South Dakota Hydrology Conference, April 17, Rapid City, SD.
4. Rastogi G, Sani R, Keegan N, Stetler L, and Menkhaus T. 2008. Bacterial diversity associated with abandoned mines in South Dakota. Platform presentation at the 20th Annual Environmental and Ground Water Quality Conference, March 26 &27, Pierre, SD.

Progress Report

State Water Resources Institute Program (SWRIP)

March 1, 2007, to February 29, 2008

Title: Permeable Reactive Bio-Barriers for Uranium Removal: Role of Iron Minerals on Uranium Fate and Transport

Principle Investigators:

Drs. Rajesh Sani, Sookie S. Bang, and David Dixon
Department of Chemical and Biological Engineering
South Dakota School on Mines and Technology
Rapid City, SD 57701 USA

Graduate Student:

Raghu Nandan Gurram
Department of Chemical and Biological Engineering
South Dakota School on Mines and Technology
Rapid City, SD 57701 USA

Introduction

Contamination of soil and water by uranium (U) is problematic because U takes hundreds of millions of years to decay radioactively and it is toxic and carcinogenic to biota. The fate and transport of U is governed by its oxidation state, which is either hexavalent {U(VI)} or tetravalent {U(IV)}. In its hexavalent state, U is very soluble and travels along with water, but U in the tetravalent state is insoluble and essentially immobile (Wall and Krumholz 2006). Under anaerobic conditions, several microorganisms are known to reduce U from its hexavalent state to its tetravalent state, thus decreasing its solubility and trapping it in the soils (Lovley et al. 1993; Lovley and Phillips 1991; Senko et al. 2002). U(VI) can also be reduced/removed from solutions abiotically for example, reduction by hydrogen sulfide (Hua et al. 2006; Sani et al. 2005; Lovley and Phillips 1991), adsorption of U on galena and pyrite (Behrends and Cappellen 2005), reduction of U(VI) by Fe(II) sorbed on to iron minerals (Jang et al. 2007; Liger et al. 1999). The cost effectiveness and low solubility ($K_{sp} = 10^{-61}$; Truex et al. 1997) of U(IV), however, shows that the microbial reduction of U is an effective approach for U immobilization (Tucker et al. 1997). The proposed research is aimed at elucidating the transport and chemical stability of uraninite formed when U flows through a biologically reactive soil matrix containing U(VI)-reducing bacteria e.g., sulfate-reducing bacteria (SRB). Specifically, we plan to construct permeable reactive bio-barriers with the U(VI)-reducing SRB, *Desulfovibrio Desulfuricans* G20 in bench-scale sand columns and quantify the removal of U across the barrier. We chose the *Desulfovibrio desulfuricans* G20 (SRB) since it can reduce U (Suzuki et al., 2003) and has been widely studied in its applications for bioremediation of U-contaminated waters (Abdelouas et al. 1999; Anderson et al. 2003; Steven et al. 2007).

Research Objectives

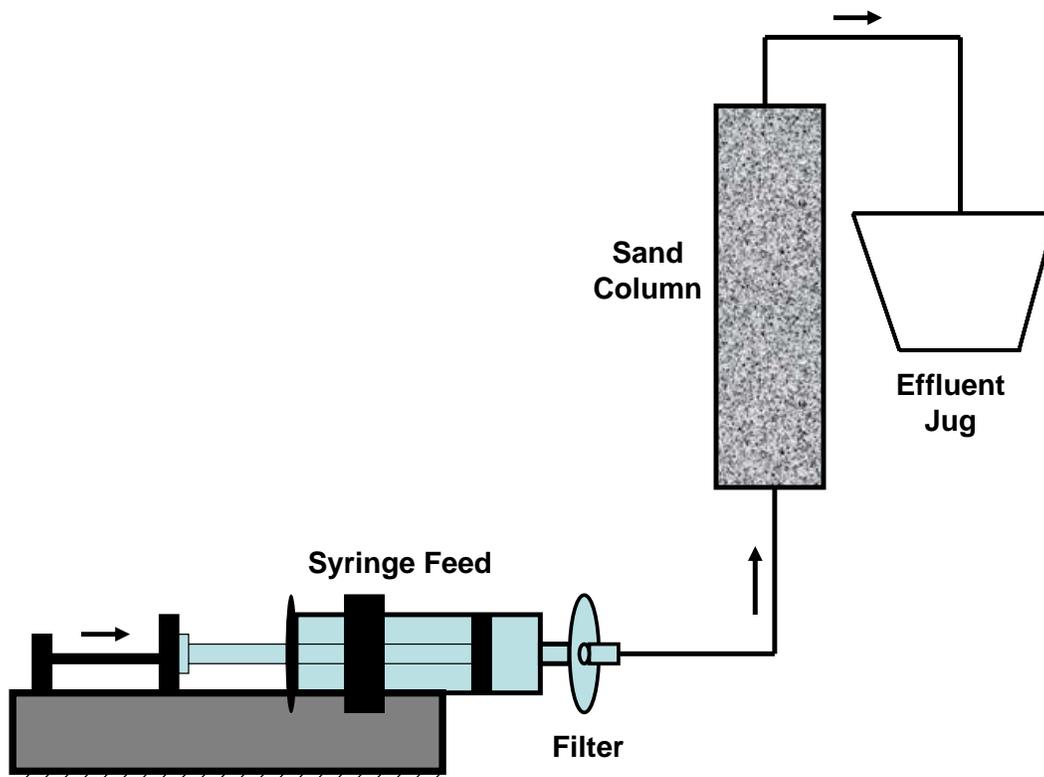
The main objectives of the research are i) to find out microbes present in the U-contaminated sites and ii) establish bio-barriers in columns to remove U. To establish bio-barriers, we will quantify

differences between U immobilization due to direct enzymatic reduction and sulfide-mediated U reduction, the effect of Fe-bearing soil minerals on the desorption/re-oxidation of bioreduced U, and finally performance of bio-barriers for U(VI) remediation.

Methodology

Bacterial diversity was characterized in soil samples collected from two abandoned uranium mines, the Edgemont and the North Cave Hills, South Dakota using 16S rRNA gene analysis. Soil characterization was carried out using X-ray fluorescence spectroscopy (XRF). To prepare bio-barriers for U removal, *Desulfovibrio desulfuricans* G20 was grown anaerobically in serum bottles containing a Metal Toxicity Medium (MTM, Sani et al. 2001) with two buffer systems {bicarbonate and 1,4-piperazinediethane sulfonic acid disodium salt monohydrate (PIPES), each at 30mM and pH 7}. Sodium lactate and sodium sulfate were used as electron donor and terminal electron acceptor, respectively. Other medium components were calcium chloride dehydrated, ammonium chloride, magnesium sulfate, yeast extract, and tryptone. The pH was adjusted to 7.2 with 1 N HCl. The serum bottles containing media were autoclaved and put immediately in an anaerobic chamber under vacuum (34 kPa) to remove headspace oxygen. The serum bottles were sealed with butyl rubber septa, capped and crimped with an aluminum seal, and pressurized with ultrapure nitrogen at 68.95 kPa above atmospheric pressure.

Establishment of the U removing bio-barriers is currently being done using anoxic MTM with and without iron mineral. Hematite (redox sensitive mineral) and quartz sand (redox insensitive mineral), or quartz sand only, and SRB (*Desulfovibrio desulfuricans* G20) will be packed in a soil column - Hydro-Purge II Format Type (120 mL Capacity, 100psig pressure, 5.5 x 9 inches, 0.25 inches tube fittings (Alltech GC Gas Purifiers); and MTM with U will be fed as show in Figure. Influent and effluent sampling will be done periodically for U, lactate, acetate, and sulfate. After breakthrough, column feed solutions will be oxygenated and delivered to the columns with syringe pump to quantify the effect of Fe-bearing soil minerals on the re-oxidation of reduced U.



Schematic of the experimental setup

Principal Findings and Significance for the project

The major findings include the phylogenetic analysis of soil collected from the Edgemont and North Cave Hills site, SD. The Edgemont was predominantly composed of phylotypes related to phylum *Acidobacteria* followed by *Proteobacteria* while soil from the North Cave Hills site was predominated by *Bacteroidetes* followed by *Proteobacteria*. Results from our study showed that highly diverse and well-adapted bacterial populations were present in these uranium-contaminated sites. Diversity indices indicated that bacterial communities at the North Cave Hills site were much more diverse than those at the Edgemont site. X-ray fluorescence spectroscopic analysis of major and trace elements of soil samples showed higher metal contaminations including U at the Edgemont site than at the North Cave Hills site as shown below in Table.

Major elements (% weight)	Edgemont site	North Cave Hills site
SiO ₂	63.14	44.21
TiO ₂	0.41	0.25
Al ₂ O ₃	15.07	5.46
FeO	4.47	1.93
MnO	0.21	0.07
MgO	1.11	0.79
CaO	1.58	2.35
Na ₂ O	1.38	0.55
K ₂ O	2.08	1.49
P ₂ O ₅	0.81	0.51
Trace elements (mg/kg dry soil)		
U	8	2
Ni	17	3
Cr	45	27
Sc	8	4
V	80	35
Ba	460	510
Rb	111	49
Sr	297	157
Zr	163	106
Y	29	15
Nb	15.4	5.2
Ga	22	8
Cu	19	53
Zn	92	122
Pb	22	11
La	32	16
Ce	67	31
Th	15	13
Nd	26	14
Cs	5	3
As	3	ND

Techniques and protocols developed in this project will be directly applicable for field treatability testing of U immobilization and remobilization rates to provide data that scientists, engineers, regulators, and stakeholders can use to determine the feasibility and level of risk associated with in-situ bio-immobilization on a site-specific basis. The proposed experiments will provide data to enable evaluation of factors that may influence the long-term stability and bioremediation potential of sulfate-reducing bio-barriers under geochemical conditions that may be expected in natural environments. In addition, the data obtained can be used to develop mathematical models for predicting stability of bio-reduced U as a function of space and time, based on a mechanistic understanding of the complex interactions between iron minerals, microbes, and U. This project has also supported following presentations:

Presentations

- Sani RK, Peyton BM, Ginn TM, Spycher NF, and Dohnalkova A. 2008. Subsurface uranium fate and transport: Biogeochemical functions of nanocrystalline uraninite oxidation by iron minerals. Platform presentation at the Western South Dakota Hydrology Conference, April 17, Rapid City, SD.
- Sani RK, Peyton BM, Ginn TM, Spycher NF, and Dohnalkova A. 2008. Subsurface uranium fate and transport: Biogeochemical functions of nanocrystalline uraninite oxidation by iron minerals. Platform presentation at the 20th Annual Environmental and Ground Water Quality Conference, March 26 & 27, Pierre, SD.
- Rastogi G, Sani R, Keegan N, Stetler L, and Menkhaus T. 2008. Bacterial diversity associated with abandoned mines in South Dakota. Platform presentation at the Western South Dakota Hydrology Conference, April 17, Rapid City, SD.
- Rastogi G, Sani R, Keegan N, Stetler L, and Menkhaus T. 2008. Bacterial diversity associated with abandoned mines in South Dakota. Platform presentation at the 20th Annual Environmental and Ground Water Quality Conference, March 26 & 27, Pierre, SD.

References

- Abdelouas A, Lutze W, Weiliang G, Eric HN, Betty AS and Bryan JT. Biological Reduction of uranium in groundwater and subsurface soil. *The science of the total environment*. 250:21-35, 1999.
- Anderson RT, Vrionis HA, Ortiz-Bernad I, Resch CT, Long PE, Dayvault R, Karp K, Marutzky S, Metzler DR, Peacock A, White DC, Lowe M, and Lovley DR. Stimulating the in situ activity of *Geobacter* species to remove uranium from the groundwater of a uranium-contaminated aquifer. *Appl. Envir. Microbiol.* 69:5884-5891, 2003
- Behrends T and Cappellen PV. Competition between enzymatic and abiotic reduction of uranium(VI) under iron reducing conditions. *Chemical Geology*. 220:315-327, 2005.
- Bin H, Huifang X, Jeff T and Baolin D. Kinetics of Uranium(VI) Reduction by Hydrogen Sulfide in Anoxic Aqueous Systems. *Environmental Science and Technology*. 40:4666-4671, 2006.
- Lovley DR, Phillips EJP, Gorby YA and Landa ER. Microbial Reduction of Uranium. *Nature*. 350:413 – 416, 1991.
- Lovley DR, Widman PK, Woodward JC and Phillips EJP. Reduction of Uranium by Cytochrome c3 of *Desulfovibrio vulgaris*. *Applied And Environmental Microbiology*. 59: 3572–3576. 1993
- Liger E, Charlet L, and Cappellen PV. Surface catalysis of uranium(VI) reduction by iron(II). *Geochimica et Cosmochimica Acta*. 63: 2939-2955, 1999.
- Jang JH, Dempsey BA, and Burgos WD. Reduction of U(VI) by Fe(II) in the presence of hydrous ferric oxide and hematite. Effects of solid transformation, surface coverage, and humic acid. *Water Research*. 42:2269-77, 2007.

- Sani RK, Peyton BM and Brown LT. Copper-induced inhibition of growth of *Desulfovibrio desulfuricans* G20: Assessment of its toxicity and correlation with those of Zinc and Lead. *Applied and Environmental Microbiology*. 67:4765-4772, 2001.
- Sass H, Berchtold M, Branke J, Konig H, Cypionka H and Ba-benzien HD. Psychrotolerant sulfate-reducing bacteria from an oxic freshwater sediment, description of *Desulfovibrio cuneatus* sp. nov. and *Desulfovibrio litoralis* sp. nov. *Systematic Applied Microbiology*. 21:212-219, 1998.
- Senko JM, Istok JD, Sflita JM and Krumholz LR. In-situ evidence of Uranium immobilization and remobilization. *Environmental Science & Technology*. 36:1491 -1496, 2002.
- Suzuki Y, Kelly SD, Kemner KM and Banfield JF. Microbial population stimulated for hexavalent uranium reduction in uranium sediment. *Applied and Environmental Microbiology*. 69:1337-1346, 2003.
- Pietzsch K, Hard BC and Babel W. A *Desulfovibrio* sp. capable of growing by reducing U(VI). *Journal of Basic Microbiology*. 39:365-372. 1999
- Wall JD and Krumholz LR. Uranium Reduction. *Annual Review of Microbiology*. 60: 149-166, 2006.
- Tucker MD, Barton LL and Thomson BM. Removal of U and Mo from water by immobilized *Desulfovibrio Desulfuricans*. 60:88-96, 1997.
- Truex MJ, Peyton BM and Valentine NB. Kinetics of U(VI)reduction by dissimilatory Fe(III)-reducing bacteria under non-growth conditions. *Biotechnology and Bioengineering*. 55:490-496, 1997.
- Yabusaki SB, Fang Y, Long PE, Resch CT, Peacock AD, Komlos J, Jaffe PR, Morrison SJ, Dayvault RD, White DC and Anderson RT. Uranium removal from groundwater via in situ biostimulation: Field-scale modeling of transport and biological processes. *Journal of Contaminant Hydrology*. 93:216-35, 2007.

Alternative Irrigation Water Management Strategies to Conserve Water

Basic Information

Title:	Alternative Irrigation Water Management Strategies to Conserve Water
Project Number:	2007SD105B
Start Date:	3/1/2007
End Date:	2/28/2009
Funding Source:	104B
Congressional District:	First
Research Category:	Engineering
Focus Category:	Irrigation, Water Use, Models
Descriptors:	
Principal Investigators:	Todd P. Trooien

Publication

1. Heeren, Derek M., Hal D. Werner, and Todd P. Trooien. 2007. Evaluation of Deficit Irrigation Strategies for Corn. ASABE Regional Meeting. Fargo, ND.
2. Heeren, Derek M. 2008. Evaluation of Deficit Irrigation Strategies for Corn. MS Thesis. South Dakota State University. Brookings, SD.
3. A paper based on this research has been accepted for the IA International Conference in Anaheim, CA. Additional manuscripts are also being prepared.

Progress Report

State Water Resources Institute Program (SWRIP)

March 1, 2007, to February 29, 2008

Title: Alternative Irrigation Water Management Strategies to Conserve Water

Investigators: Dr. Hal Werner, South Dakota State University
Dr. Todd Trooien, South Dakota State University

Introduction:

Competition for water is increasing while a growing world population requires more food production. One study predicts that in the year 2050, there will be an annual water shortage of 640 billion cubic meters (Spears, 2003). Since irrigation is the largest consumptive use of water in many places, accounting for 65% of the fresh water use in the 22 western states (calculated from USGS, 2000), proper irrigation water management is critical to make the best use of the water available.

Project Information:

As competition for irrigation water supplies becomes greater, it will be necessary for irrigators to optimize the use of the water available to them and reduce the risk of large yield losses. Considerable research has been conducted on irrigation scheduling strategies including deficit water applications. However, specific strategies have not been developed to address the management characteristics of center pivot irrigation. The objective of this research was to use crop models adapted for center pivot irrigation water management to evaluate strategies to achieve water conservation.

South Dakota State University Management Software was used to simulate center pivot irrigation and corn growth and yield at seven locations across the Great Plains. Sixteen to 24 years of weather data were used for each site. Thirty irrigation strategies were evaluated across three soil water holding capacities and three pumping rates. Evapotranspiration was calculated with the tall reference Penman-Monteith equation and dual crop coefficients for corn. The yield ratio, calculated with a normalized transpiration ratio, was used along with water use data to evaluate irrigation strategies.

Strategies with high water use efficiencies performed well across all treatments and locations. The recommended maximum yield strategy is 30-60-30 (strategies were defined by the minimum available soil water (%) for early, middle, and late season). Using the recommended maximum yield strategy resulted in water savings and either increased or slightly decreased yields. Recommended deficit strategies are 15-50-0, 0-30-0, and 0-15-0 for minimal, moderate, and severe water restrictions. Annual variation in yield is greatest when water is most limited. For deficit irrigation, the benefit of high water holding capacity soils may be limited to sites with frequent large rainfall events (>25 mm). Pumping rate had a small effect on the general yield-

irrigation relationship, although limited pumping rates resulted in limited maximum yields for arid locations. Evapotranspiration forecasting was not found to be necessary for good irrigation management. Simulating irrigation and crop growth appears to be an effective way to evaluate best irrigation management practices and deficit irrigation strategies.

Evaluation of Manure Application Risk on Frozen Soils

Basic Information

Title:	Evaluation of Manure Application Risk on Frozen Soils
Project Number:	2007SD106B
Start Date:	3/1/2007
End Date:	2/28/2009
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Water Quality, Agriculture, Climatological Processes
Descriptors:	
Principal Investigators:	Dennis Todey, David R. German

Publication

Progress Report

State Water Resources Institute Program (SWRIP)

March 1, 2007, to February 29, 2008

Title: Evaluation of manure application on frozen soils

Investigators: Dr. Dennis Todey, South Dakota State University
Mr. David German, South Dakota State University

Introduction:

Graduate Student Joanne Anderson has been developing soil temperature climatologies for stations in South Dakota to quantify the last 25 years of soil temperature trends and overall distribution of fall freeze-up and spring thaw. The general trends across the state indicate that fall frost occurs in mid-November and spring freeze-out is in mid-March. This is similar to what is currently being used for limitation of manure application in South Dakota. These are general averages. There is much year to year variability.

We entered this study expecting to find a trend in these dates related to changes in winter temperatures coincident with the warming of winters over the last 25 years. What we have found from analysis of a few stations is that the length of the frozen soil period is maintaining similar duration over the last 25 years. But there has been a shift of a few days later in the fall for freeze-up and a few days later thawing in the spring. Further analysis is being done on additional stations and to assess more about the temporal changes.

We have also purchased and placed 2-levels of soil temperature/moisture sensors on our two field locations in Brookings and south of Brookings (near Madison). These sensors were used for two purposes:

- Tracking freeze-up and thawing in different locations in the fields
- Measuring changes in temperature and moisture during rained-on simulations.

Paired plots were used in field for watershed analysis for rained-on periods, as described in the amended grant. The plot work was moved outside in conjunction with other work being done on this same fields where manure application was occurring in known fields. Manure was applied before snow and after snow and rained on with and without snow cover.

Initial analyses show some interesting differences between the water samples gathered from different manure applications (on ground, on snow, etc). Further analysis must be done to determine significant differences in the run-off samples.

Information Transfer Program Introduction

Information dissemination is an important part of the South Dakota Water Resources Institute (SD WRI) program. Public outreach and dissemination of research results are cornerstones of the South Dakota Water Resources Institute's Information Transfer Program. Dissemination of research results are accomplished through journal publications, abstracts, posters, and presentations at conferences. Emphasis is placed on providing opportunities for graduate students to present their findings.

Public outreach takes several forms, including a website (<http://wri.sdstate.edu>), SD WRI newsletters, fact sheets, and water quality interpretations. Water Resources Institute staff continue to provide interpretation of analysis and recommendations for use of water samples submitted to the Water Quality Lab. SD WRI staff also routinely responded to questions from the general public, other state agencies, livestock producers, and County Extension Educators. These inquiries include water quality and quantity, stream monitoring, surface water/ground water interactions, livestock poisoning by algae, lake protection and management, fish kills, soil–water compatibility, manure runoff, and irrigation drainage.

Public outreach also includes hosting water quality workshops for adults as well as water education for youth. These educational opportunities include hands–on activities at water festivals, field trips, presentations, workshops, and demonstrations.

Institute staff participate in state, federal, and local committees and organizations. Feedback to these agencies is often given in the form of presentations at state meetings, local water development boards, conservation districts, sanitary districts, and citizen groups.

Information Transfer

Basic Information

Title:	Information Transfer
Project Number:	2005SD52B
Start Date:	3/1/2005
End Date:	2/29/2008
Funding Source:	104B
Congressional District:	First
Research Category:	Social Sciences
Focus Category:	Education, Water Quality, None
Descriptors:	
Principal Investigators:	Van C Kelley, David R. German, Jennifer L. Pickard

Publication

1. German, D., N. Thiex, C. Wright. 2008. Interpretation of Water Analysis for Livestock Suitability. South Dakota State University, Brookings, SD.

FY2007 Information Transfer Program
South Dakota Water Resources Institute

PUBLIC OUTREACH

Public outreach and dissemination of research results are cornerstones of the South Dakota Water Resources Institute's Information Transfer Program. Information Transfer takes many forms. The South Dakota Water Resources Institute *Water News* newsletter is in its fourth year of publication. This is an effective format to disseminate information about activities in which the Institute participates, funds, and promotes. The newsletter is published quarterly via e-mail, as well as a link on the SD WRI homepage (<http://wri.sdstate.edu>) in PDF format allowing for viewing of past and present issues. Water-related research including updates on present projects, notification of requests for proposals, state-wide water conditions, conferences, as well as information on youth activities are highlights in each issue. SD WRI's web site has been redesigned to improve user access to the updated links which include publications to help diagnose and treat many water quality problems. The site allows the public to keep in touch with the activities of the Institute, gather information on specific water quality problems, learn about recent research results and links with other water resource related information available on the Web. The "Research Projects" section of the SD WRI web is updated with past and present research projects, highlighting the Institute's commitment to improving water quality.

Another important component of the Institute's Information Transfer Program is the Water Quality Laboratory (WQL). The lab was consolidated with the Oscar E. Olson Biochemistry Labs in 2004. The WQL provides important testing services to water users across the state. Water Resources Institute staff continues to provide interpretation of analysis and recommendations for use of water samples submitted for analysis. Assistance to individual water users in identifying and solving water quality problems is a priority of the Institute's Information Transfer Program. Interpretation of analysis and recommendations for suitability of use is produced for water samples submitted for livestock suitability, irrigation, lawn and garden, household, farmstead, heat pump, rural runoff, fish culture, and land application of waste. New topics for publication including fecal coliform and tastes, colors, and odors in water have been researched. These publications facilitate public awareness and promote education.

An extensive library of information has been developed and continues to be updated on-line. Information regarding analytical services available at the Oscar E. Olson Biochemistry Labs Water Quality Laboratory and information that may be used to address drinking water problems is available on-line.

The drought in western South Dakota which continued to a lesser degree in 2007 has demonstrated the importance of the services offered by the Water Quality Laboratory. The inherent quality of surface waters in western South Dakota is commonly low, leading to chronic livestock production problems. However, drought has intensified this problem for livestock producers in these semi-arid rangelands. Many dugouts and ponds degraded to the point of causing cases of livestock illness and, in some instances, deaths. Although water quality problems in western South Dakota are common, some isolated cases of

livestock illness and deaths due to poor surface water quality have occurred in eastern South Dakota as well. Lab services provided by the WQL and interpretation of results by WRI staff is important to livestock producers as they try to manage risks associated with water shortages and poor water quality.

SD WRI made the region's drought situation a priority in its outreach/information transfer efforts by posting information for farmers and ranchers on this subject on the Institute's web page (<http://wri.sdstate.edu/drought.htm>). The SDSU Agricultural Communications Department also developed a press release and special web page dealing specifically with the drought. This web page referred producers who had questions about their water quality to the SD WRI web page.

SD WRI staff also routinely responded to water resource questions unrelated to laboratory analysis from the general public, other state agencies, livestock producers, and County Extension Agents. These inquiries include water quality and quantity, stream monitoring, surface water/ground water interactions, aquatic plant identification, livestock poisoning by algae, lake protection and management, fish kills, soil-water compatibility, and irrigation drainage. WRI continues to provide soil and water compatibility recommendations for irrigation permits to the SD Division of Water Rights.

SD WRI staff assisted in implementing the second annual Eastern South Dakota Water Conference held October 29-31, 2007 to provide a forum for water professionals to interact and share ideas. The Eastern South Dakota Water Conference was started in 2006 to serve as a mechanism to educate participants on water resource issues in South Dakota.

The 2007 Eastern South Dakota Water Conference was held in conjunction with the 52nd Annual Midwestern Groundwater Conference at the Sioux Falls Convention Center October 29-31, 2007. This was the second year for the Eastern South Dakota Water Conference. The steering committee was chaired by Derric Iles of the South Dakota Geological Survey and Van Kelley, Director of the South Dakota Water Resources Institute at South Dakota State University (SDSU). Other members included: David German and Jennifer Pickard (South Dakota Water Resources Institute--SDSU), Mike Crane (USGS-EROS Data Center), Jay Gilbertson (East Dakota Water Development District), Delvin DeBoer (Water & Environmental Engineering Research Center—SDSU), Paul Boyd (US Army Corps of Engineers).

The call for abstracts and speakers was released in May 2007. SDWRI staff member Jennifer Pickard designed a website (<http://wri.sdstate.edu/esdwc>) where participants could review the conference timeline and pre-register and pay for the conference.

The conference began with a tour of the USGS Earth Resources Observation and Science (EROS) Data Center and the US Army Corps of Engineer's Gavins Point Dam and fish hatchery on October 29th. Concurrent sessions on October 30th focused on groundwater and surface water while sessions on October 31st included information management and water quality, and surface water and water supply.

Concurrent sessions throughout the conference offered information important to a wide array of stakeholders including engineers, industry, public officials, agricultural producers, and conservation groups. SDWRI staff member David German gave

presentations on manure management BMPs based on soil phosphorus and phosphorus runoff on a watershed scale.

Water is an important piece of the economic future of South Dakota, and this conference served as a mechanism to educate participants on this resource. It is anticipated that this conference will be an annual event. To find more information and view abstracts from the 2007 conference, go online to <http://wri.sdstate.edu/esdwc>.

AGENCY INTERACTION

The SD WRI Information Transfer program includes interaction with local, state, and federal agencies/entities in the discussion of water-related problems in South Dakota and the development of the processes necessary to solve these problems. One of the most productive agency interactions is with the Non-Point Source (NPS) Task Force. The NPS Task Force coordinates, recommends, and funds research and information projects in this high priority area. Participation on the NPS Task Force allows SD WRI input on non-point source projects funded through the state and has provided support for research in several key areas such as soil phosphorus versus runoff phosphorus relationships, biomonitoring, and lake research. Many of the information transfer efforts of the Institute are cooperative efforts with the other state-wide and regional entities that serve on the Task Force.

Another example of this interaction to solve water quality problems is a program started by the Cooperative Extension Service (CES) to help livestock producers identify unsuitable water sources. The CES provides many of its Extension Educators with hand-held conductivity meters for use in the field. If samples are shown to be marginal by field testing, they are sent to the Water Quality Lab for further analysis. Often, high sulfates limit the use of waters that have elevated conductivity.

Another important interaction is with the South Dakota Department of Environmental and Natural Resources (DENR). Completion of Total Maximum Daily Load (TMDL) studies on South Dakota lakes has been a priority for DENR over the past several years. SD WRI is providing technical assistance to local sponsors working with DENR to complete the TMDL water quality assessments on several publicly owned lakes that do not have an established lakeside community.

Several other local and state agencies conduct cooperative research with SD WRI or contribute funding for research. Feedback to these agencies is often given in the form of presentations at state meetings, local boards, and public informational meetings for non-point source and research projects.

YOUTH EDUCATION

Non-point source pollution contributes to the loss of beneficial uses in many impaired water bodies in South Dakota. An important part of reducing non-point pollution is modifying the behavior of people living in watersheds through education. Programs designed to educate youth about how their activities affect water is important because attitudes regarding pollution and the human activities that cause it are formed early in life. For these reasons, Youth Education is an important component of SD WRI's Information Transfer Program.

Water Festivals provide an opportunity for fourth grade students to learn about water. Since they began in 1992 Water Festivals have been held in seven sites including Spearfish, Rapid City, Pierre, Huron, Vermillion, Brookings and Sioux Falls. Since their inception, Water Festivals in South Dakota have impacted approximately 90,000 Fourth Graders state wide. The Big Sioux Water Festival, held locally in Brookings, has recorded attendance of over 16,600 kids, 2,150 adults and 3,450 workers since 1993. SD WRI staff members continued to support and participate in Water Festivals throughout the state in FY2007. SD WRI also supported water quality education in local schools including classroom presentations and assisting local educators with field trips.

ADULT EDUCATION

David German (SDWRI) and Dennis Skadsen (Day Conservation District) presented a lake water quality workshop at Enemy Swim Lake made possible with funds through an EPA 319 grant. The idea behind the workshop stemmed from the fact that most water quality events like Water Festivals are usually targeted towards children.

Another reason for doing the workshop was the idea of “teaching the teachers.” Helping adults learn about water quality and providing them with useful information encourages them to teach others in their home community how their behaviors affect the lake. A PowerPoint presentation was available for participants to take home to help encourage them to share what they learned at the workshop.

Several hands-on activities were developed that helped workshop participants share their new-found knowledge of lakes. These activities included “The Lake Game” and demonstrations of lake stratification, photosynthesis and aquatic plants, as well as biomagnification using “mercury cookies.” The group also made their own Secchi discs to monitor the transparency of the lakes they live on. This allows participants to monitor the water quality of a lake and provides an avenue for individuals to take an active part in monitoring their lake.

Two workshops are planned in 2008. Camp Bob Marshall near Custer, SD will host a workshop July 25-27th and NeSoDak Camp near Waubay, SD will host a workshop August 15-17th. Both workshops will offer participants the opportunity to earn continuing education credits.

As part of SDWRI’s outreach to the agricultural community, staff hosted a booth at DakotaFest, a three-day agricultural fair held in August each year near Mitchell, South Dakota, which draws approximately 30,000 people. A large selection of literature regarding water quality is available for distribution and SDWRI staff members field a variety of questions concerning water quality and current research from farm and ranch families. A taste of “good water” versus “bad water” (high in magnesium sulfate) was used to demonstrate that water quality cannot always be determined by visual inspection. Producers also drop off water samples to be taken back to the WQL for analysis.

PUBLICATIONS

Distribution of research findings to the public, policy makers and sponsors of non-point source pollution control projects is another important component of the SD WRI Information Transfer program. This is needed so that the lessons learned through

research and implementation projects are not lost as the next generation of projects develops. SD WRI is committed to making this material readily available to persons within South Dakota as well as in other states. A library is maintained at SD WRI to make these materials readily available. Abstracts of research projects funded by the institute have been placed on the WRI web site along with photos and summaries showing progress on these projects will be published on the site as they become available.

Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	6	0	0	0	6
Masters	3	0	0	0	3
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	11	0	0	0	11

Notable Awards and Achievements

Process and apparatus to reduce the amounts of arsenic in water: Dr. Cathleen J. Webb, Dr. Arden D. Davis, and Dr. David J. Dixon; U.S. Patent Application Serial No. 10/861,586; patent pending. Continuation-in-part reviewed in 2007.

Mr. Raghu Nandan Gurram was awarded Nelson Fellowship for AY08–09 based on his merit and research activities related to uranium removal bio-barriers.