Kansas Water Resources Research Institute

Annual Technical Report

FY 2000

Introduction

The Kansas Water Resources Research Institute (KWRRI) is managed by Kansas State University. Within K-State, KWRRI is administratively under the Kansas Center for Agricultural Resources and the Environment (KCARE). Dr. Bill Hargrove is the Director of KCARE and KWRRI. In addition, there is a base staff of an Accounting Specialist and a part-time Information Specialist. The Institute provided partial support for five research projects this past year. Two additional research projects were concluded during the year. Additionally, we supported three student interns and hosted a statewide water conference. We requested a special state appropriation of $200,000 to KWRI to support water research, but it did not pass. The primary water issues in Kansas include TMDL implementation and conservation of the Ogallala aquifer.

Research Program

Basic Information

Title:	The Kansas Water Institute: An Integrated Electronic Community of Knowledge
Project Number:	E-01
Start Date:	3/1/1999
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Education, None, None
Descriptors:	Water Resources, Information Systems, World Wide Web, Collaboration
Lead Institute:	University of Kansas
Principal Investigators:	Robert Worth Buddemeier, William Leonard Hargrove

Publication

1. None at this time
2. None at this time
3. None at this time
4. FY2000 Annual Report
5. Water and the Future of Kansas Conference

6. None at this time

Problem and Research Objectives:

The problem to be addressed is that of communication barriers and less than optimal cooperation among the various water research professionals that are capable of contributing to holistic solutions to the problems of water resource use and management in the state of Kansas.

The approach to be taken in addressing this is development of effective electronic (WWW) systems and links in the form of a "Virtual Water Institute." This cooperative endeavor will (1) Link, cross-reference and integrate existing electronic resources of relevant agencies and the institutions; (2) Develop specific listings of research needs, issues, and expertise/information throughout the state; and (3) provide mechanisms for exchange and sharing of both information and ideas, and for electronic collaboration.

Methodology:

The techniques to be used will be establishment and coordination of multiple websites using the information display and download technology, search engines, and interactive communication links appropriate to the audience(s) addressed. Contents, format and design will be overseen by a committee of interrelated parties from the participating institutions, with actual development coordinated through the project and institutional webmasters. Feedback from users will become an increasingly important part of site development, and candidate audiences and participants will progressively be contacted and invited to use and contribute to the site.

Principal Findings and Significance:

Accomplishments to date may be summarized as follows:

- The VKWRI websites, http://www.vkwri.org, hosted by Kansas State University, and http://www.kgs.ukans.edu/KWRC/vkwri/, based at the Kansas Geological Survey, have functioned as catalysts in developing expanded WWW presences among nearly all of the water related agencies in the state. Research, regulatory, planning and management agencies have greatly expanded the content and sophistication of their web sites, in many cases along lines laid out by the VKWRI effort.
- The VKWRI experience and infrastructure have served as a basis for related or derivative developments. Foremost among these have been the development of the electronic Atlas of the High Plains Aquifer (http://www.kgs.ukans.edu/HighPlains/atlas), a wide range of information services, tools and products provided by KSU Research and Extension (http://www.oznet.ksu.edu/), and a web-site presence for the developing High Plains Coalition, a consortium of state geological surveys from the states overlying the High Plains aquifer (http://www.kgs.ukans.edu/KWRC/IMproposal). This site also served as the information base for developing a preproposal to the NSF Information Management program for a water-resource oriented informatics program around the High Plains regions

- The KGS and the USGS have arrived at an understanding to cooperate in a regional-scale informatics network that would integrate state and local level electronic databases and information sources with the regional and national data providers. This effort is now in the early development stages.

The VKWRI project wrapped up its period of funding with a presentation at the Water and Future of Kansas Conference in March 2001, where it was apparent that there were continued needs and opportunities for developing web-based information linkages among agencies and projects. Subsequent developments in Kansas regarding the potential management of the Ogallala aquifer for long-term sustainability have further highlighted the need and opportunities for a general purpose 'information broker' site to link and integrate the offerings of mission-oriented agencies.

Although indirect achievements have been substantial, the direct status and impact of the site has been less than desired. This stems in part from the preference of institutions and programs to support their own web presence rather than cooperate with a general project. Although understandable and to some extent desirable, this means that the VKWRI site has not yet achieved its potential as an information broker and a web resource for small organizations that cannot support their own WWW presence efectively

The KGS team of web designers and data managers has been expanded by other informatics-related research funding, and the VKWRI is being maintained as the needs and opportunities for community web presence are assessed. In view of the next generation of specialized interactive tools and data sources coming on line, the need for a directory service has increased rather than decreased. It is expected that the outcomes of the Kansas Ogallala aquifer project, the high Plaions Coalition development, and the KGS-USGS cooperative informatics initiative, will identify the most appropriate niche for a more focused development of a second-generation VKWRI site.

Basic Information

Title:	A Field Assessment of Direct-Push Technology for Site Characterization Investigation
Project Number:	00-1
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Groundwater, Water Quality
Descriptors:	Direct Push, Site Characterization, Hydraulic Tests, Water Sampling, Hydrostratigraphy
Lead Institute:	University of Kansas
Principal Investigators:	James J. Butler, Li Zheng

Publication

1. None at this time
2. None at this time
3. FY2000 Annual Report
4. Butler, J.J., Jr., Healey, J.M., McCall, W.G., Garnett, E.J., and S.P. Loheide II, Hydraulic tests with direct-push equipment, Ground Water, accepted pending final revisions. Butler, J.J., Jr., Garnett, E.J., and J.M. Healey, Analysis of slug tests in formations of high hydraulic conductivity, Ground Water, in review. McCall, W.G., Butler, J.J., Jr., Healey, J.M., Lanier, A.A., Sellwood, S.M., and E.J. Garnett, A dual-tube direct-push method for vertical profiling of hydraulic conductivity in unconsolidated formations, Journal of Environmental and Engineering Geosciences, in review (invited paper). Schulmeister, M.K., Zheng, L., Butler, J.J., Jr., Healey, J.M., McCall, W., and D.A. Wysocki, Detailed hydrostratigraphic characterization with direct-push electrical conductivity profiling (abstract), Eos, v. 81, no. 19, p. S238, 2000. Butler, J.J., Jr., Healey, J.M., McCall, W., Loheide, S.P., and E.J. Garnett, Hydraulic tests with direct-push equipment (abstract), Eos, v. 81, no. 19, p. S239, 2000
5. Butler, J.J., Jr., Franseen, E.K., Xia, J., Schulmeister, M.K., Zheng, L., Weiss, T., Byrnes, A.P., Healey, J.M., and R. Miller, Experimental assessments of the utility of direct-push profiling and ground-penetrating radar for hydrostratigraphic investigations (abstract), Program and Abstracts SEPM/IAS Research Conf. Environmental Sedimentology: Hydrogeology of Sedimentary Aquifers, p. 27, 2000. Lanier, A.A., Sellwood, S.M., Butler, J.J., Jr., Healey, J.M., McCall, W., and E.J. Garnett, Direct-push hydraulic profiling in an unconsolidated alluvial aquifer (abstract), GSA 2000 Annual Meeting Abstracts with Program, v. 32, no.7, p. A271, 2000. McCall, W., Butler, J.J., Jr., Healey, J.M., and E.J. Garnett, A dual-tube direct push method for vertical profiling of hydraulic conductivity in unconsolidated aquifers (abstract), GSA 2000 Annual Meeting Abstracts with Program, v. 32, no.7, p. A522, 2000. Garnett, E.J., McCall, W., Butler, J.J., Jr., and J.M. Healey, Determination of hydraulic conductivity with slug tests in direct push tools (abstract), Proc. of the NGWA 2000 Petroleum Hydrocarbons and Organic Chemicals in Ground Water Conf., p. 158, 2000. Butler, J.J., Jr., Healey, J.M., Schulmeister, M.K., and L.

Zheng, A field assessment of direct-push technology for site characterization investigations (abstract), Proc. 18 th Annual Water and the Future of Kansas Conf., p. 21, 2001. OTHER PRESENTATIONS (NO ABSTRACTS) Butler, J.J., Jr., and J.M. Healey, Advances in slug testing for improved site characterization: New concepts, field techniques, and data analysis, two day workshop sponsored by the Midwest Geosciences Group and the University of Texas at Arlington, Arlington, Tx., June 22-23, 2000. Butler, J.J., Jr., Review of aquifer tests, invited presentation to the Department of Agriculture, Division of Water Resources Brown Bag Seminar, Topeka, Ks., July 19, 2000. Butler, J.J., Jr., Improving the design and analysis of slug tests, invited presentation for the Advances in Site Characterization for Environmental and Engineering Projects at Glaciated Sites Workshop, Minneapolis, Mn., October 7, 2000. Butler, J.J., Jr., and J.M. Healey, Utilization of direct-push technology: Introduction and explanation of new technology for obtaining geologic and hydrologic data, invited presentation to the Department of Agriculture, Division of Water Resources Fall 2000 Conference, Topeka, Ks., October 11, 2000. INFORMATION TRANSFER Results were presented at three national meetings (American Geophysical Union, Spring 2000, Washington; Geological Society of America, Nov. 2000, Reno; National Ground Water Association 2000 Petroleum Hydrocarbons and Organic Chemicals in Ground Water Conference, Nov. 2000, Los Angeles) and two workshops (Midwest Geosciences Group workshop at the University of Texas at Arlington, June 2000; Advances in Site Characterization for Environmental and Engineering Projects at Glaciated Sites Workshop, Minneapolis, October 2000). Results were also presented to the Kansas water resources community at the 18th Annual Water and the Future of Kansas Conference in Manhattan (March 2001) and at two presentations to personnel of the Division of Water Resources of the Kansas State Department of Agriculture in Topeka. Two web sites were set up at the Kansas Geological Survey (www.kgs.ukans.edu/Hydro /DirectPush/index.html and www.kgs.ukans.edu/Hydro/WellTests/index.html) for rapid dissemination of the results of this project. Reports and a spreadsheet for analysis of slug tests can

6. OTHER REPORTS Butler, J.J., Jr., and E.J. Garnett, Simple procedures for analysis of slug tests in formations of high hydraulic conductivity using spreadsheet and scientific graphics software, Kansas Geological Survey Open-File Rept. 2000-40, 31 pp. and associated spreadsheet and data files, 2000 (also available in an electronic form at http://www.kgs.ukans.edu/Hydro /Publications/OFR00_40/index.html). Butler, J.J., Jr., Lanier, A.A., Healey, J.M., Sellwood, S.M., McCall, G.W., and E.J. Garnett, Direct-push hydraulic profiling in an unconsolidated alluvial aquifer, Kansas Geological Survey Open-File Rept. 2000-62, 36 pp., 2000 (also available in an electronic form at http://www.kgs.ukans.edu/Hydro/Publications/OFR00_62/index.html).

PROBLEM AND RESEARCH OBJECTIVES

Currently, groundwater resources provide more than 85% of the water used in Kansas. Many of the important aquifers for drinking water supplies consist of unconsolidated sediments lying in past or present river valleys. Protection of these resources is a matter of highest public concern. The quality of the water in alluvial aquifers can be threatened by contamination via a number of mechanisms, including point-source contamination from sites on the overlying flood plain (e.g., landfills, animal waste lagoons, hazardous waste storage areas, and accidental chemical releases) and intrusion of saline river water (e.g., Arkansas River). Effective management of these important groundwater resources depends on our ability to reliably assess the threat posed by existing and potential contamination. This assessment, however, is only as good as the data on which it is based. Using conventional field methods, large amounts of time and money can be expended without necessarily improving our knowledge of conditions in the subsurface. There is a critical need for efficient and scientifically sound field methods that will enable us to acquire the information necessary to reliably evaluate the severity of contamination threats in a practically feasible manner. The development of such a "tool set" for regulators and practicing water-resources professionals in Kansas is the primary goal of this project.

This research is directed at the development and evaluation of a set of practical site-characterization techniques designed to significantly reduce the uncertainty associated with hydrogeologic investigations. This set of techniques will be based on direct-push methods, an innovative alternative to conventional drilling approaches that has been developed since the mid-1980s for obtaining soil-gas, water, and core samples at sites of groundwater contamination. The major focus of this research will be the development and evaluation of direct-push techniques for the detailed hydraulic, geochemical, and stratigraphic characterization of unconsolidated alluvial deposits. The information that can be obtained from such a detailed characterization is essential for siting waste storage and disposal facilities, designing effective remediation schemes, and evaluating the risks to human health and the environment posed by existing contamination. Although direct-push technology is currently limited to environmental site investigations, it has the potential for much broader application. As a secondary focus of this project, we will attempt to extend the use of direct-push technology to include characterization of stream-aquifer interactions, a key component of the hydrologic budget of many aquifers in Kansas. In the first year of this project, we had the following four objectives:

1) Development and field assessment of a set of practical guidelines for performing hydraulic tests in direct-push equipment;

2) Begin work on a method for obtaining profiles of hydraulic conductivity using direct-push equipment;

3) Perform calibration and verification of direct-push electrical conductivity logging;

4) Begin work on a method for obtaining profiles of geochemistry using direct-push equipment.

METHODOLOGY

The majority of the work in the first year of this project was performed at the Geohydrologic Experimental and Monitoring Site (GEMS), a Kansas Geological Survey (KGS) research site located just north of Lawrence, Kansas. GEMS has been the site of a great deal of previous work on groundwater flow and transport, and spatial/temporal geochemical variability. This previous work enables the tasks of this project to be performed in a very controlled field setting.

A series of pumping and slug tests were performed at GEMS using direct-push equipment. Drawdown during the pumping tests was measured at both conventional observation wells and temporary direct-push installations. Slug tests were performed in direct-push installations and nearby conventional observation wells in intervals of high and moderate permeability. A spreadsheet-based method for the analysis of slug tests in highly permeable formations was developed as part of this work.

A dual-tube method for obtaining profiles of hydraulic conductivity was developed. This method was evaluated by comparing hydraulic conductivity estimates to those from multilevel slug tests and dipole flow tests performed in nearby conventional wells.

The calibration and verification of direct-push electrical conductivity (ec) logging was accomplished by comparing ec logging responses to results of grain-size analyses of cores collected over the same intervals. A series of traverses (up to 300 m in length) were performed to better assess the potential of ec logging for stratigraphic characterization.

Initial work on direct-push geochemical profiling was performed using an exposed screen profiling tool. Geochemical field parameters and water samples were obtained from a direct-push installation and compared to those from multilevel sampling wells at the same levels.

PRINCIPAL FINDINGS AND SIGNIFICANCE

The principal findings and their significance will be discussed in the context of the four objectives of the project:

Objective 1: Development and field assessment of a set of practical guidelines for performing hydraulic tests in direct-push equipment – A series of practical guidelines were developed for the performance of both pumping tests and slug tests in direct-push equipment. These guidelines, which were evaluated in a controlled field setting, are summarized in an upcoming article in the journal Ground Water. We expect that this article will become the standard reference for consultants, researchers, and regulators working with direct-push equipment. In addition, a new method for the performance and analysis of slug tests in formations of very high hydraulic conductivity was developed. This method is described in a KGS Open-File Rept. (on the web) and an article currently in review in the journal Ground Water;

Objective 2: Begin work on a method for obtaining profiles of hydraulic conductivity using direct-push equipment – An initial method for hydraulic profiling was developed and demonstrated in a controlled field setting. This method is described in a KGS Open-File Rept. (on the web) and an

invited paper currently in review in the Journal of Environmental and Engineering Geosciences. This method allows information about vertical and lateral variations in hydraulic conductivity to be obtained at a level of detail that was not previously possible with direct-push equipment. Near the end of the first year of this project, Butler and Healey went to a former Soviet military base near Berlin, Germany and demonstrated the approach to German scientists and consultants (this demonstration was funded through a cooperative research project with the University of Tuebingen);

Objective 3: Perform calibration and verification of direct-push electrical conductivity logging – An initial assessment of the potential of direct-push electrical conductivity (ec) logging was completed. This assessment, which included acquisition of core samples, demonstrated that direct-push ec logging has great potential for rapid delineation of site stratigraphy. The results were reported in two national meetings. A paper describing this assessment is currently in preparation;

Objective 4: Begin work on a method for obtaining profiles of geochemistry using direct-push equipment – An initial comparison of water samples taken from similar depths using conventional multilevel sampling wells and a direct-push profiler was completed. Excellent agreement was found for temperature, pH, conductivity, NO_3, SO_4, and Cl. Modifications to sampling equipment to allow a wider range of chemical parameters to be assessed are currently underway.

Basic Information

Title:	Real Time Crop Water Management and Irrigation Scheduling Web Site
Project Number:	00-5
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Education, Irrigation, None
Descriptors:	World Wide Web, Water Management, Irrigation Scheduling, Crop Water Use
Lead Institute:	Kansas State University
Principal Investigators:	Gary Allan Clark, Daniel A. Andresen

Publication

1. None at this time
2. None at this time
3. None at this time
4. FY2000 Annual Report
5. None at this time
6. None at this time

Problem and Research Objectives

Irrigation accounts for over 95% of the water use in southwest Kansas. In an efforts to help reduce aquifer declines the State Water Plan has the following objectives: (3.1.5) by 2010, reduce the number of irrigation points of diversion for which the acre feet per acre (AF/A) water use exceeds the representative regional AF/A standard (1.0 AF/A in eastern Kansas, 1.5 AF/A in central Kansas, 2.0 AF/A in western Kansas) and those that overpump the amount authorized by their water rights; (3.1.6) by 2010, reduce the level of decline rates within the Ogallala Aquifer and implement enhanced water management in targeted areas; (3.1.12) by 2010, target data collection, research projects, and information sharing activities to address specific water resource issues as identified in the Kansas water planning process and to support and guide water resource program operations; and (3.1.14) by 2010, provide educational activities to ensure that all Kansans have the knowledge necessary to understand the hydrologic cycle and to have an appreciation for demands and influences upon the state's water resources.

As a result increasing interest in irrigation scheduling and crop water management has occurred throughout Kansas. While traditional access to technical and educational information exists through workshops, seminars, field days, and published materials, busy schedules and other conflicts limit participation and access to these events. However, access to and interest in the use of the World Wide Web has been growing at a fast pace. This project is designed to improve the transfer of water management knowledge and technology for improved agricultural crop production and resource conservation by using a Water Management Web Site housed within the Kansas Water Resources Institute. Once the site is developed, established, and in use, other water resources related research results and extension information can be posted for additional technology transfer and enhanced knowledge of improved water management and crop production practices.

The goal of this project is to develop, test, and display a user friendly Web Site that will provide a personal crop production and water management account system with real time weather data for improved water use efficiency, crop management and planning, and increased economic returns. This Water Management Web Site will be designed to help the user with their irrigation scheduling and water management decisions. It will create crop water management accounts for individual users based upon input of their crop, soil, and geographic location. The Site will access the currently available real time weather data, estimate and log the crop water use, and display the results graphically for the user. The Site will update each water management account on a daily basis without requiring continual access by the user. This should enhance the use and availability of the automated weather data that must currently be accessed either daily or every three days in two of the Kansas Ground Water Management Districts. The individual will input site-specific rainfall and irrigation amounts to complete the water budget.

Methodology

A web site was designed and created to aid the farmers in the task of water management and irrigation scheduling. The web site was modeled after an Excel-based irrigation scheduling spreadsheet called KanSched. That program uses a data input page for the user to input information on the planting date, hybrid maturity, soil characteristics, and crop growth characteristics. A (water) budget page and Management Chart are used to display the field water status for field interrogation and irrigation scheduling purposes. The web site will provide automatic links and electronic access to a Kansas weather database maintained by the Kansas State University Research and Extension State Climatologist (http://www.oznet.ksu.edu/wdl/bbw_et.htm). Educational pages will be developed with the link to the main input page and will include information on soil properties; crop water use (ET) and crop coefficients; the fundamentals of maintaining a field water balance and irrigation scheduling; crop growth and development; and irrigation system characteristics (efficiency, uniformity, net irrigation requirements).

The basic architecture of the entire application is shown in Figure 1. The weather data is downloaded daily from different weather stations all over Kansas and is available as a text file which can then be downloaded for processing or into a clients system. A small Java program converts the available data into a format where it can be inserted into the database. One of the goals is to provide for server side scalability by restricting most of the computation to the client end. The central figure in the system is the webserver, which acts as the interface between the client and the database. Most of the middle tier is comprised of servlets running on the webserver. The clients system runs a Java applet that computes the soil water content based on the input provided by the users at the beginning of the growing season. Whenever the client accesses the program, their water budget is automatically updated with the current weather data.

Principal Findings and Significance

The website program has been created and tested with data from the year 2000. Figures 2 though 6 show various screen shots of the interface pages including the login screen, initialization screen, input page, budget page, and management chart.

The website has been deployed on Sun Solaris, Redhat Linux 6.0 and Microsoft Windows NT platforms and has been easy to configure on all of them. The client side applet has been tested on Microsoft Internet Explorer 5.0 and 5.5, Netscape Navigator 4.7 and 6.0 and Mozilla 0.7 browsers on Windows 98/NT and on Netscape Navigator 4.7 on Sun Solaris and Redhat Linux 6.0. All browsers require the user to download the Java plug-in except for Netscape 6.0 and Mozilla, which come bundled with the plug-in. The applet is not very bulky and amounts to about 120 KB. Download times for the same were found to be excellent over several different connections. Less than a minute of download time was required over a very slow 33.6 Kbps

modem. The application also worked through a firewall because all the communication is being done over HTTP.

One drawback was identified when the user operated the applet on a Windows NT machine. Under such conditions, they need to have administrative rights to that machine and should be logged on as an administrator.

During the next year, the algorithms will be updated to accommodate non-irrigated crops and the server side will be re-structured to allow for greater modularity and ease of maintenance. The use of XML will be increased, allowing the retargeting of server-generated content to mobile WAP-enabled devices such as cellular phones. A thorough season-long evaluation of the system will be conducted for accuracy and to verify its correlation with the KanSched scheduling program.

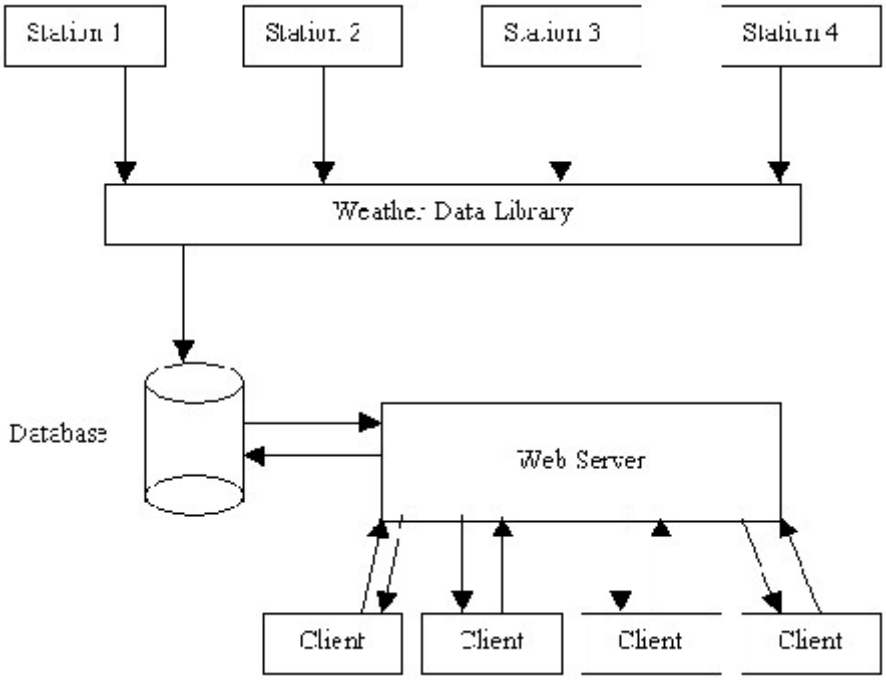

Figure 1. General structure of the system with a basic three-tier architecture associated with most Internet applications.

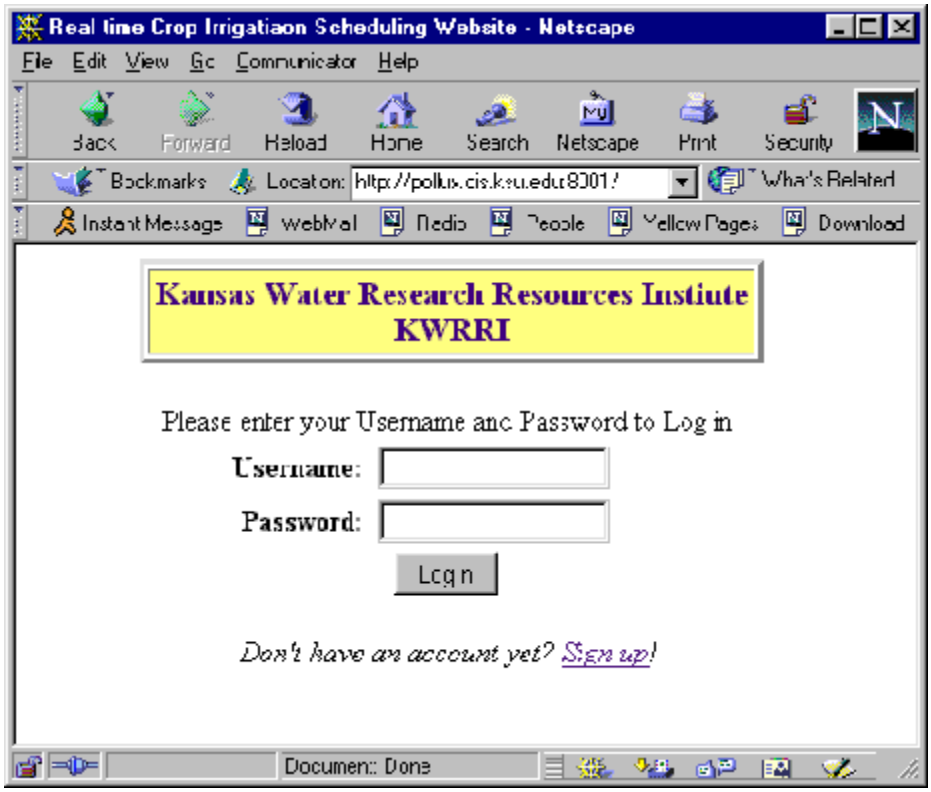

Figure 2. Login screen.

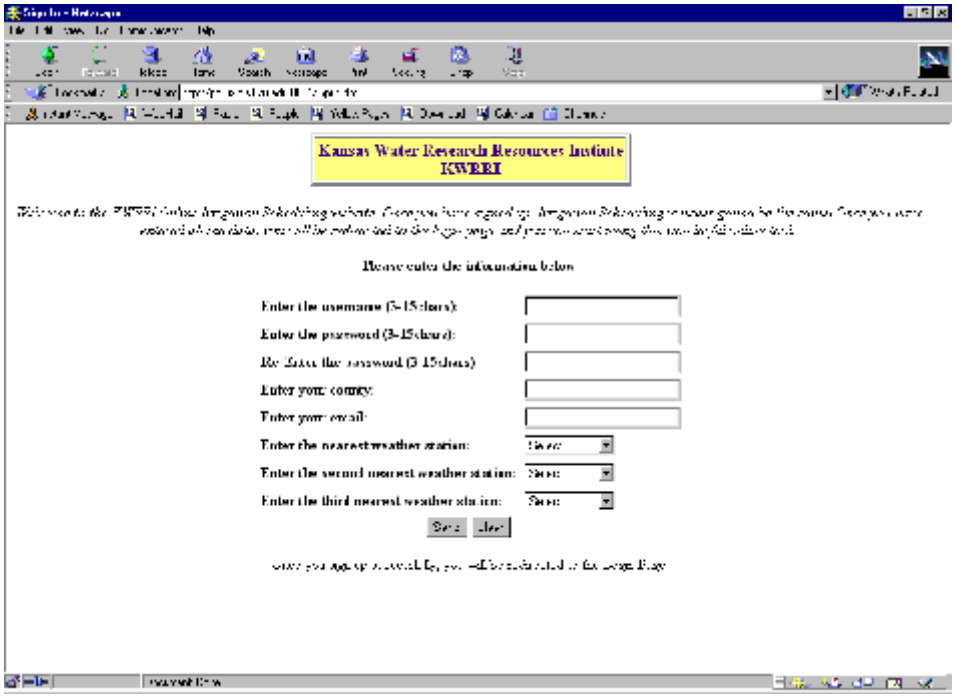

Figure 3. General sign-in and initialization page

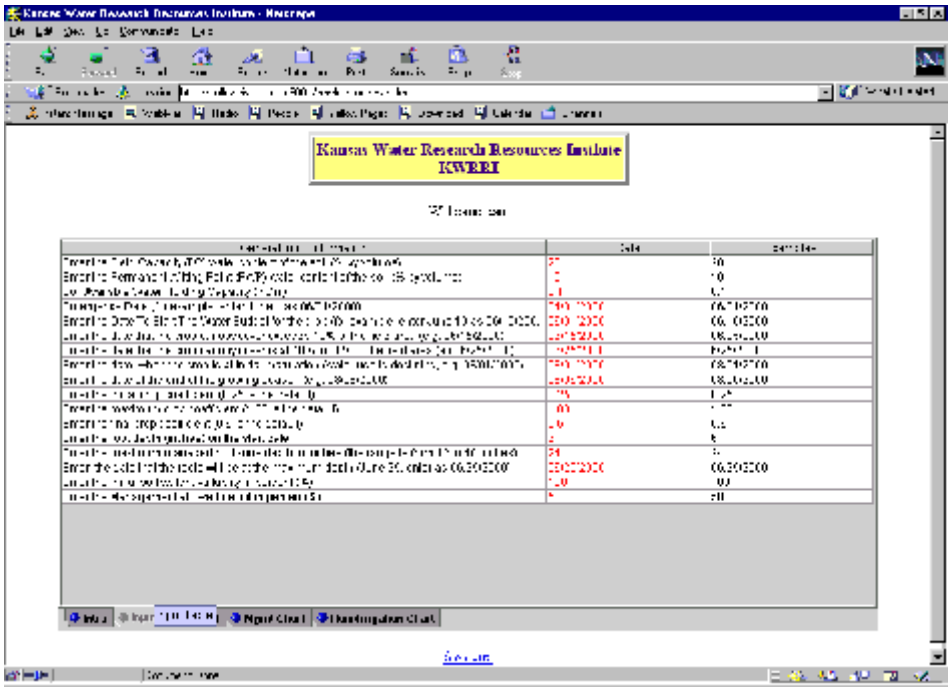

Figure 4. Input page.

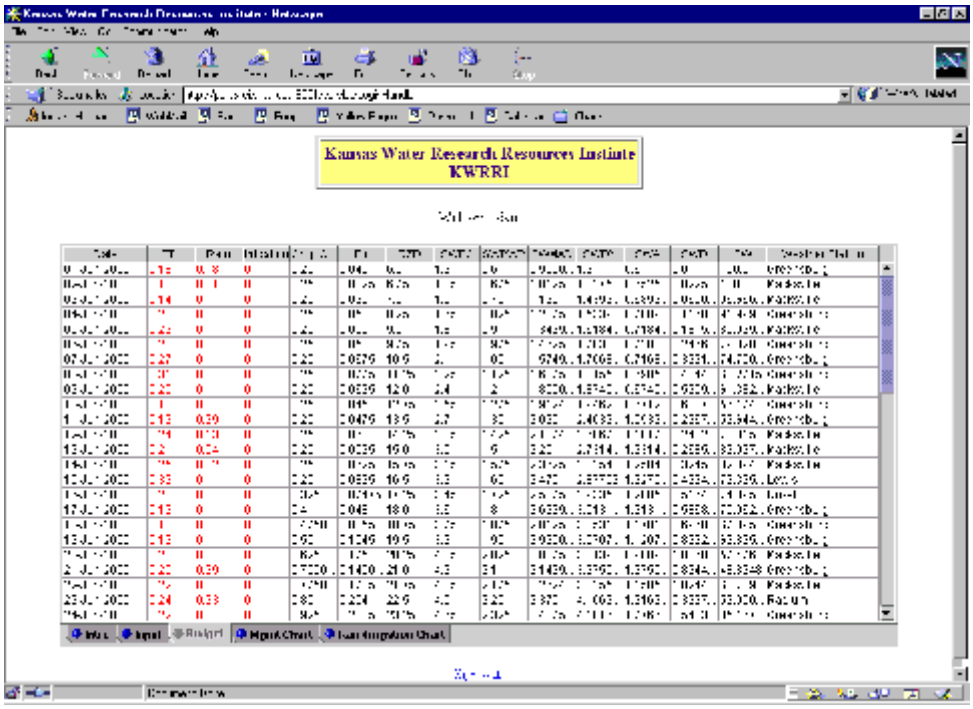

Figure 5. Water budget page.

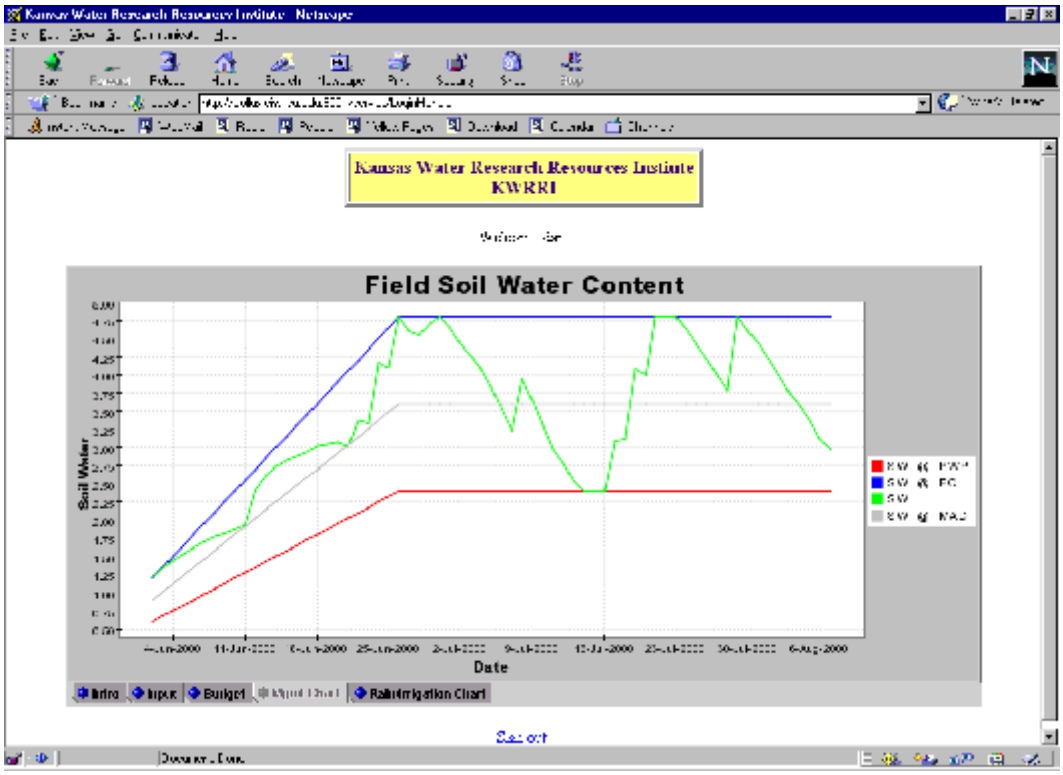

Figure 6. Water management chart.

Basic Information

Title:	Sources and Control of Geosmin in Midwestern Water Supply Reservoirs
Project Number:	B-02
Start Date:	9/1/1998
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Water Supply, Water Quality, Treatment
Descriptors:	Geosmin, taste and odor, algae, cyanobacteria, actinomycetes, reservoir management
Lead Institute:	University of Kansas
Principal Investigators:	Stephen J. Randtke, Frank deNoyelles

Publication

1. None at this time
2. None at this time
3. None at this time
4. FY2000 Annual Report
5. None at this time
6. None at this time

Problem and Research Objectives:

Seasonal taste and odor problems are perhaps the single greatest public relations issue many water utilities face because consumers generally rely on the taste and odor of their drinking water as the primary indicators of its safety. Some Midwestern utilities spend large sums of money for taste and odor control, and some have even gone so far as to build additional treatment facilities or develop a new source of water; but their efforts are not always successful.

In the great majority of Midwestern taste-and-odor episodes involving constituents present in the raw (untreated) water, consumers complain of an earth or musty odor. Geosmin (trans-1,10-dimethyl-trans-9-decalol), a chemical that imparts an earthy taste and odor to water, has been found to be, or has been suspected of being, the primary culprit in most of these cases. However, information regarding the sources of geosmin in Midwestern reservoirs, and the factors influencing its production, release, and decay, is lacking. There is also a critical lack of information regarding: the effectiveness of in-lake management techniques for controlling geosmin in Midwestern reservoirs; options for treating drinking water when extremely high levels of geosmin, e.g., 200 to 500 nanograms per liter (ng/L) are encountered; and the occurrence and control of a another compound, 2-methylisoborneol (MIB), that imparts a musty taste and odor to water but seems to be less prevalent than geosmin.

The goal of this project was to help managers of water supply reservoirs, treatment plant superintendents, and others to control geosmin in Midwestern drinking water supplies. Specific objectives included:

1) establishing the relative importance of various sources of geosmin production in typical Midwestern reservoirs;

2) developing a fuller understanding of the physical, chemical, and biological factors influencing geosmin production, release, and decay in Midwestern reservoirs;

3) assessing the ability of both traditional and novel in-lake management techniques to reduce or minimize geosmin production, and to prevent severe episodes; and

4) identifying and developing drinking water treatment processes able to control geosmin during severe episodes when routine methods, e.g., adsorption on powdered activated carbon (PAC), as typically practiced, are inadequate.

Since the analytical method developed for use on this project was also suitable for determining MIB, the study objectives were subsequently extended to include MIB as well.

Methodology:

The project objectives were pursued through an integrated combination of field sampling, mesocosm experiments, and laboratory experiments.

Several reservoirs with a history of taste and odor problems, as well as water treatment facilities drawing water from these reservoirs, were routinely monitored for geosmin and MIB in an effort to observe the seasonal occurrence and spatial distribution of geosmin and MIB in various Midwestern reservoirs, to detect the onset of taste-and-odor episodes (so that additional studies focusing on the nature of the episodes could be initiated), and to examine the effectiveness of current treatment practices for removing geosmin and MIB. Additional lakes and reservoirs were irregularly sampled as opportunities to do so arose. Whenever possible, sampling was coordinated with other water quality investigations so that more robust sets of water quality data could be developed (and to leverage project resources).

The investigators initially planned to rely on microenvironment sampling during taste and odor episodes to identify and characterize potentially significant sources of geosmin. Microenvironment sampling involves collecting samples in algal mats, weed beds, brush piles, areas of standing timber, deep and shallow waters, aerobic and anaerobic sediments, mud flats, and influent streams. However, the reservoirs being monitored did not experience severe taste- and-odor episodes during the study; and, once the monitoring results began to be obtained, it appeared that the occurrence of geosmin was primarily related to larger-scale phenomena. Accordingly, field sampling efforts were redirected toward examining the temporal and spatial variability of geosmin on a broader scale, e.g., in riverine versus lacustrine environments and as a function of season, nutrient availability, and other factors likely to impact the growth of algae and actinomycetes.

Mesocosms, model ecosystems that can be manipulated to simulate a range of physical, chemical, and biological conditions, were used to examine the production and decay of geosmin and MIB under more controlled conditions. Larger ponds, which more closely mimic lakes and reservoirs in that their bottoms and banks are composed of soil, were also used to study geosmin and MIB production. In several experiments involving mesocosms and ponds, the concentrations of nitrogen and phosphorus were manipulated to create a suite of nutrient conditions, some of which strongly favored the growth of blue-green algae (i.e., cyanobacteria).

Laboratory experiments were conducted to obtain a deeper (e.g., mechanistic) understanding of phenomena observed in the field and in mesocosm experiments, and also to examine potentially useful treatment techniques on a small scale. Several pilot-scale experiments had initially been planned for the second year of the project, to examine selected in-lake management and in-plant treatment techniques. However, some of the planned pilot studies could not be conducted due to the lack of taste-and-odor episodes during the project, while others were deemed premature and were replaced with additional mesocosm and laboratory experiments.

Principal Findings and Significance:

Low concentrations of geosmin were typically present in most of the water bodies monitored, but MIB was often undetectable. High concentrations of geosmin and MIB occurred episodically and exhibited significant temporal and spatial variation. Geosmin concentrations tended to be higher in the riverine and transitional zones of reservoirs than in the deeper lacustrine zones; and they also tended to be higher in epilimnetic waters than in hypolimnetic waters. Thus, geosmin and MIB concentrations measured at a single location, e.g., a raw water intake, are not necessarily representative of those occurring elsewhere in

a lake or reservoir.

During the course of the study, a number of minor taste-and-odor episodes were reported by various water utilities cooperating in the project and by other utilities who contacted the investigators because they had heard about the project. The great majority of these episodes involved earthy/musty taste and odor; and in every case involving an earthy or musty taste or odor that appeared to originate in the source water, geosmin or MIB was detected at a level high enough to cause consumer complaints. These results support the assumption that geosmin and MIB are the compounds primarily responsible for the earthy/musty taste and odor problems being reported by Midwestern water utilities.

Available evidence points to certain species of blue-green algae (cyanobacteria), rather than actinomycetes, as the primary source of geosmin and MIB in Midwestern reservoirs. Thus, it is reasonable to expect that lake management strategies designed to reduce the abundance of blue-green algae will reduce taste-and-odor episodes associated with geosmin and MIB, provided that these strategies are at least equally effective in controlling the particular strains of blue-green algae that produce geosmin and MIB (e.g., *Anabaena*).

Geosmin and MIB production are species, strain, and life-stage specific. Since a complex set of factors and conditions cause one species to thrive at the expense of others and cause a geosmin- or MIB-producing species to produce more or less geosmin or MIB, it is not presently possible to accurately predict when a taste and odor episode associated with geosmin or MIB will occur. However, trends and tendencies can be identified based on experience with a particular body of water or by conducting a detailed study of a particular water body.

Mesocosm experiments demonstrate that nutrient (nitrogen and phosphorus) enrichment, even under conditions leading to severe blooms of blue-green algae, does not necessarily result in increased geosmin or MIB concentrations. Therefore, placing the blame for a taste and odor problem on "eutrophication" or "non-point source pollution" is overly simplistic.

At the concentrations typically responsible for taste and odor episodes, geosmin and MIB do not serve as primary substrates, i.e., their concentrations are too low to support microbial growth. However, the can be biological degraded by a process known as cometabolism. Dissolved geosmin biodegrades much more rapidly than intracellular geosmin; geosmin typically biodegrades faster than MIB; and both geosmin and MIB biodegrade much more slowly in colder water which, in addition to reduced volatility, helps explain the tendency of taste and odor episodes to be more prolonged in the late fall or winter. The rate of degradation also varies greatly from one water source to another, and laboratory experiments conducted as part of this project demonstrated that such differences are attributable to differences in the microbial communities naturally present in the water. This may account, in part, for differences in taste and odor episodes among lakes having apparently similar characteristics; and it also suggests that geosmin can be effectively controlled biologically, either in the source water or at the treatment plant, if the proper assemblage of organisms can be grown and maintained. Efforts to accomplish this by adding ethanol, methanol, and other substrates to lake water were not successful.

Effective treatment processes for geosmin and MIB are available, e.g., ozonation, various advanced

oxidation processes, and granular activated carbon (GAC) adsorption in post-filter contactors having a relatively long detention time. However, most such processes are quite expensive and are therefore difficult to justify, especially to treat an intermittent problem, unless they are also intended to meet other needs (e.g., disinfection) or the consumers are sufficiently upset about the taste of their water to support a costly process to improve it. Granular activated carbon adsorption, in the filter-cap mode, is less effective for removing geosmin and MIB than commonly believed.

For most utilities, the most practical treatment alternative is powdered activated carbon (PAC) adsorption. Many utilities already use PAC, but some lack the feeding capacity to adequately address severe episodes while others, due to physical constraints or operational practices, do not obtain full use of the capacity of the PAC they add. Removal of geosmin and MIB by PAC was found to be influenced by PAC type and by the addition of various chemicals (potassium permanganate, polymer, chlorine, and chlorine dioxide), but not by lime addition. Process efficiency can be improved by building up the PAC concentration in a solids-contact reactor and perhaps by split dosing, i.e., dividing the dosage in half and treating the water twice. Additional removal can also be achieved by applying PAC at multiple points upstream of basins having an adequate contact time.

A proprietary zeolite adsorbent was found to be superior to PAC, on a weight basis, for removing geosmin and MIB; but further evaluation is needed to determine whether the use of such an adsorbent would be cost effective for a water utility and whether the zeolite can be reused.

Basic Information

Title:	The Relationship Between Soil Test Phosphorus Levels and Phosphorus in Surface Runoff in Manure Amended Soils: A Rainfall Simulator Study
Project Number:	D-01
Start Date:	3/1/1999
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Surface Water, Nutrients, Non Point Pollution
Descriptors:	Phosphorus
Lead Institute:	Kansas State University
Principal Investigators:	Gary M. Pierzynski, Gary Allan Clark

Publication

1. None at this time
2. None at this time
3. None at this time
4. FY2000 Annual Report
5. None at this time
6. Ethridge, K., G.M. Pierzynski, and G. Clark. 2000. Cattle manure effects on surface runoff losses of phosphorus. Agron. Abs. P. 391. Am. Soc. of Agron., Madison, WI.

Problem and Research Objectives

Our primary objective is to determine the relationship between soil test P levels and total, dissolved, and bioavailable P in surface runoff from manure amended soils.

Methodology

A rainfall simulator was constructed according to modified plans presented in Edwards et al. (1992). Briefly, this consists of an aluminum frame to hold the spray nozzles, associated water piping, pressure gauges, and electrical wiring that will provide uniform simulated rainfall to a plot 1 by 2 meters in size. The nozzles are 305 cm (10 feet) above the soil surface, spaced 190.5 cm (75 inches) apart, and consist of two TeeJetTM ½HH-SS30WSQ nozzles designed to supply 75 mm/h of simulated rainfall by maintaining a flow rate of 126 mL/s at each nozzle and controlling the relative on/off spraying times for each nozzle. Intensity and uniformity was determined by collecting and measuring rainfall amounts within an area corresponding to the plot size that was used in the field study. The frame was fitted with tarps to provide a windscreen. Two soil series were selected for this study. Sites were selected that had an area of uniform slope (>2%) sufficiently large to accommodate all of the plots, an area that had a single soil series, and that had a relatively low initial soil test P level (<20 mg/kg Bray-1 extractable P). Both sites are located at the North Agronomy Farm near the KSU campus in Manhattan. Plots were established that had a range of soil test P levels produced by applying varying amounts of cattle manure. Five soil test P levels were used per site in triplicate. The plot areas were clean tilled prior to the establishment of the treatments. Pre-weighed amounts of manure were be applied by hand to plots 2 by 4 meters in size and incorporated approximately 10 cm into the soil using a disk. A 1 by 1.5 meter area in the center of each plot was used to collect runoff. This area was split in half to create two 1 by 0.75 m plots. A subplot treatment was created by planting wheat or oats in one of the small plots while leaving the other fallow. The small plots were delineated by placing metal borders 5 cm above and below ground to isolate the runoff. A runoff collection gutter was installed at the downslope edge of each runoff plot to divert runoff to a collection point. A small plastic bucket was used at the collection point. A submersible pump was used to pump runoff from the small bucket to large buckets for determination of runoff volume and sample collection. The first rainfall simulation was conducted in October 1999 followed by addition runs in March, July, and October 2000. The plots were pre-irrigated to thoroughly wet the soil but not to the point of generating runoff. The pre-irrigation normalizes antecedent soil moisture content and reduces the time to runoff for the actual runoff experiments. Runoff measurements began 24 hours after pre-irrigation. The rainfall simulator applied water at 75 mm/h until runoff occurred for 30 minutes. All runoff was collected in 30 gallon trash cans, weighed to determine runoff volume, and sub-sampled for analysis. Water samples were stored at 4°C until analysis. Sediment concentrations in water samples were determined by passing a known volume of water through a pre-weighed 0.45 micron filter. The filter and sediment were be dried to a constant weight at 105°C and the sediment yield was determined by the increase in mass. Total P in unfiltered samples was determined after digestion in perchloric and nitric acid. Dissolved P was determined by measuring the P concentration in filtered samples. Bioavailable P was be determined by the iron-oxide strip procedure. Immediately prior to the rainfall simulation, soil samples were collected from 0-5 cm from each plot. The holes made by the soil probe were backfilled with soil taken from the

plot area outside of the area used for collecting runoff. The samples were analyzed for moisture content, Bray-1 extractable P, and bioavailable P. The relationships between soil test P levels and P in runoff were determined using regression analysis.

Principal Findings and Significance

Manure applications ranged from 0 to 200 Mg/ha so P applications ranged from 0 to 760 kg/ha. Bray-1 extractable P concentrations were increased to nearly 500 mg/kg at both sites by the addition of manure. Results from all four runoff events showed a significant increase in soluble P and bioavailable P loss in runoff with increasing manure amounts. Total P loss however did not significantly increase. Manure additions decreased sediment concentrations significantly, which likely reduced the total P concentrations because of the relatively large proportion of the total P in runoff associated with sediment. The total amount of soluble P in the runoff for each individual manure amount remained fairly constant throughout the experiment. Runoff volume and sediment concentration showed a decreasing trend with increased manure amounts. Soil Bray P showed a significant correlation with soluble P loss in runoff with R^2 values of 0.61, 0.78, 0.67, and 0.75 for the first through fourth simulations, respectively (Figure 1). Soil Bray P showed a significant correlation with bioavailable P loss in runoff with R^2 values of 0.39, 0.69, 0.67, and 0.75 for the first through fourth simulations, respectively (Figure 2). For both measurements, the slope of the line decreased slightly between the fall 1999 and spring 2000, but then did not decrease further through the fall 2000. Results from the cropped versus fallow plots showed that the cropped side had significantly lower runoff volume and therefore less sediment, soluble P, bioavailable P, and total P losses in runoff. The manure apparently increased the soil's water holding capacity and thus decreased runoff volume. The manure also decreased sediment loss. Both of these things led to an insignificant increase in total P loss with increasing manure amounts. Further analysis of the results will include looking at water-soluble phosphorus in the soil as well as the amount of phosphorus used by the crop.

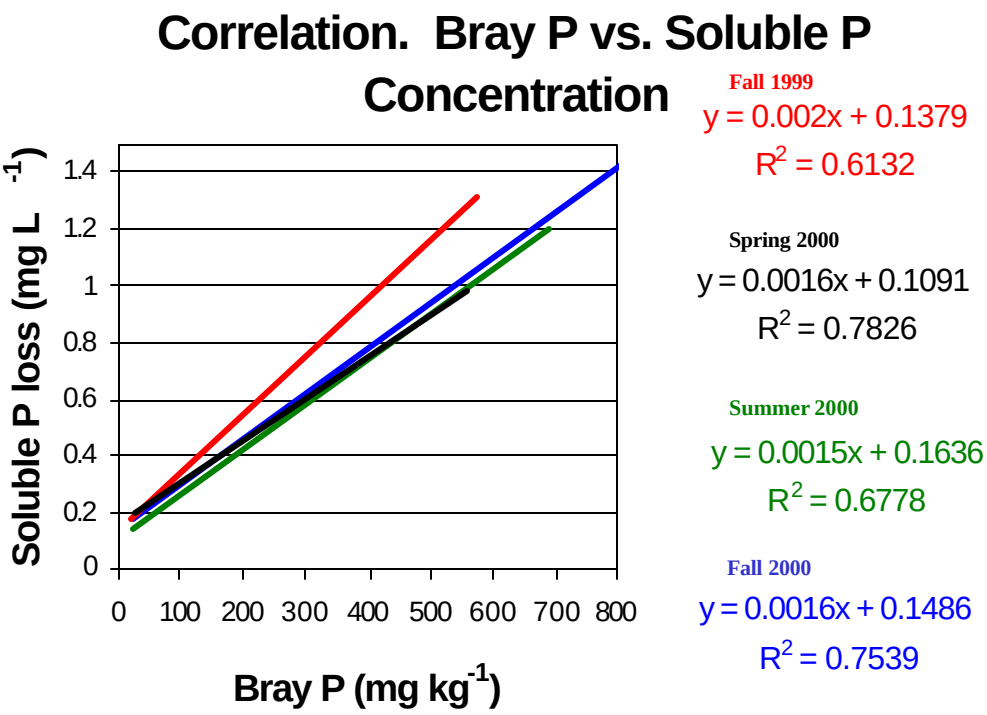

Figure 1. The relationship between Bray-1 extractable phosphorus and soluble P concentrations in runoff over time.

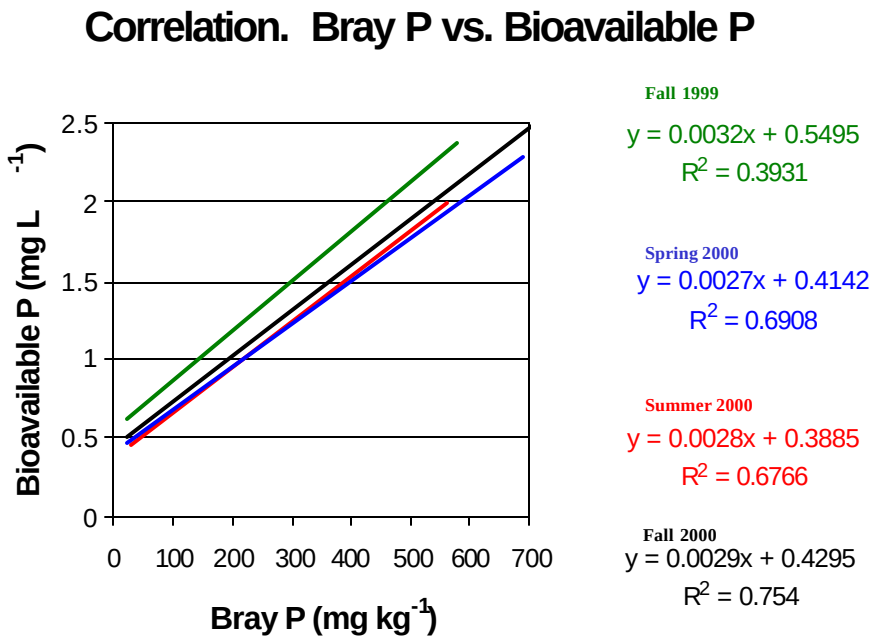

Figure 2. The relationship between Bray-1 extractable phosphorus and bioavailable P concentrations in runoff over time.

Basic Information

Title:	Endocrine Disruptors in Surface Waters: The Occurrence, Distribution, and Fate of Alkylphenol Polyethoxylates and Metabolites in Wastewater Treatment Facilities and Their impact on Kansas Rivers
Project Number:	00-4
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Waste Water, Surface Water, Non Point Pollution
Descriptors:	wastewater, endocrine disruptor, alkylphenol polyethoxylates
Lead Institute:	Kansas State University
Principal Investigators:	Kang Xia, Alok Bhandari

Publication

1. None at this time
2. None at this time
3. None at this time
4. FY2000 Annual Report
5. None at this time
6. Keller, H.L. A.J. Wagner, K. Xia, and A. Bhandari. 2001. Occurrence and distribution of 4-nonylpenol in a northeastern Kansas wastewater treatment plant. 18th Annual Kansas Water Conference. March 13, 2001. Manhattan, KS. Keller, H.L., Keller, A.J. Wagner, K. Xia, and A. Bhandari. 2001. Transformation and distribution of nonylphenol polyethoxylates (NPnEOs) and their metabolites in Northeastern Kansas wastewater treatment plants. 2001 Great Plains/Rocky Mountain Hazardous Substance Research Center Environmental Research Conference. Manhattan, KS.

Problem and Research Objectives

Our primary objective is to investigate the occurrence, distribution, and fate of estrogenic nonylphenol polyethoxylates (NPnEOs) and metabolites in municipal wastewater treatment facilities, effluent discharges, and biosolids.

Methodology

The occurrence, distribution, and fate of nonylphenol polyethoxylates and metabolites in three Kansas wastewater treatment plants (WWTPs) were investigated. Raw wastewater, primary effluent and sludge, secondary effluent and sludge, and biosolids were collected at each treatment plant one day per month from June to November 2000. The pH, ionic strength, and dissolved organic carbon content in each water sample were measured before extraction of target chemicals. The target compounds were extracted from each water sample using C18 solid phase extraction technique. High performance liquid chromatography with fluorescence detector (HPLC-FLD) was used for target compounds analysis. Solid samples were extracted using Soxhlet extraction technique before analyzed on HPLC-FLD.

Principal Findings and Significance

Concentrations of individual NPnEOs were as high as 104 mg/L in the WWTP influent and exhibited profiles similar to commercial non-ionic surfactant mixtures. No NPnEOs (n = 9-16) were detected beyond the primary clarifier indicating the longer ethoxy chains were being degraded aerobically. NPnEOs ($n \leq 5$; ≤ 40 mg/L) were present in the WWTP effluent. Minimal NPnEOs ($n \leq 3$; concentrations ≤ 2 mg/L) were detected in the aqueous phase of the dissolved air floatation tank or anaerobically digested sludge due to the sorption to the biomass. Influent concentrations of 4-NP ranged from 50 to 218 mg/L suggesting that partial anaerobic conversion of NPnEOs to 4-NP occurred during transit from the point of discharge to this WWTP. Minimal 4-NP was detected in the contact-stabilization tank, dissolved air floatation tank, or effluent due to sorption of the hydrophobic 4-NP to biomass. Concentrations of 4-NP in the aqueous phase of the anaerobically digested sludge ranged from 20-38 mg/L, a result of anaerobic transformation of NPnEOs and NPnECs while in the anaerobic digesters. The biosolids' 4-NP accounted for ~94% of the total 4-NP, both entering and produced, in the WWTP. Biosolids land application is becoming the most common means of biosolids disposal as other disposal options become cost prohibitive or heavily regulated. Given that about 7 million tons of biosolids are produced annually in wastewater treatment plants in the United States, several thousand tons of metabolites of NPnEOs could be potentially released to the soil environment through land application of biosolids. The metabolites of NPnEOs released into the soil environment can potentially enter the water environment due to runoff and leaching. Future research on the transport and transformation of metabolites of NPnEOs in biosolids-amended soil and its impact on surface and ground water quality are needed.

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Basic Information

Title:	Measuring Seepage Losses from Waste-treatment Lagoons: A Simplified Water Balance Approach for Use By Government Agencies, Consultants, and Industry
Project Number:	00-2
Start Date:	3/1/1999
End Date:	2/28/2000
Research Category:	Water Quality
Focus Category:	Water Quality, Agriculture, Groundwater
Descriptors:	Animal Waste, Lagoons, Seepage
Lead Institute:	Kansas State University
Principal Investigators:	Jay M Ham

Publication

Research Objectives

Anaerobic lagoons are used throughout Kansas to collect, store, and treat waste from concentrated animal feeding operations (e.g., swine, cattle, dairy). Most lagoons are soil-lined, and concerns have been raised that seepage losses from these facilities could pollute local groundwater. This proposal describes a simplified water balance approach for measuring lagoon seepage that could be used by consultants, state agencies, and industry.

Methods

Previous research has shown that whole-lagoon seepage rates can be determined by measuring changes in depth (ΔD) and evaporation (E) over a 5- to 10-day period (Ham, 1999; Ham and DeSutter, 1999). If waste additions and waste removal is disallowed from a lagoon, then the seepage rate, S, in mm per day, can be calculated as

$$S = \frac{(-\Delta D + P - E)}{t}$$

where P is precipitation (mm) and t is elapsed time (days). Often, P is negligible, so the crucial measurements are ΔD and E. While there are many ways to measure ΔD, the determination of E from lagoons is challenging. Ham (1999) showed that E could be determined very accurately using a bulk transfer approach (see Ham Eq. 3), a method which requires the measurement of lagoon surface temperature, wind speed, and humidity near the middle of the lagoon. In this research project, more simplified methods, namely evaporation pans, were tested as an alternative approach for measuring E.

A portable Class-A-sized evaporation pan was designed and tested (Fig. 1). The pan was made from a 4-ft-diameter stock water tank that had been cut down to a height of 25 cm (10 inches). Liquid levels in the pan were maintained using a remote water level recorder and 55-gal drum filled with waste (Fig. 2). A float-based water level recorder was placed inside the drum to record the change in depth (i.e., evaporation) over time. Deployment of the system consisted of positioning the apparatus on the berm of the lagoon and then filling the pan and drum with waste. During each test of the pan system, E was simultaneously measured using the bulk transfer approach of Ham (1999). The pan coefficient, k_p, was computed as the ratio of the actual E (measured by the Ham method) and evaporation from the pan (E_p).

$$E = k_p E_p$$

For the pan method to be viable, the value of k_p must be known or easily predicted. Pan evaporation is usually larger than actual evaporation; thus, k_p typically ranges between 0.5 and 0.8.

The pan system was tested at locations in eastern, central, and southwestern Kansas. A test also was conducted in central Oklahoma. At the southwest Kansas site, six tests were performed over a 12-month period. In addition, the pan made from the stock tank was compared to a commercial Class-A pan made from stainless steel.

Results to Date

Data show that the pan apparatus itself worked extremely well. In most cases, it was possible to monitor E_p for 10 to 14 days before the drum reservoir had to be refilled. Evaporation from the stock-tank pan was not significantly different from the commercial

Class-A pan during a 30-day test conducted near Manhattan, KS. The pan was easy to deploy, but care had to be taken to avoid any potential leaks in the plumbing. Other possible drawbacks were the accumulation of dust/debris on the pan-water surface and biogas (CH_4, CO_2) bubbles in the hose routing waste from the drum to the pan. The dust problem was worse at cattle feedlots.

Despite the favorable performance of the pan apparatus, the pan coefficients at the different test sites were highly variable. The value of k_p ranged between 0.35 and 0.8, an unaccepted range of uncertainty. Also, it was difficult to predict the value of k_p based on time of year or weather conditions. The variation in k_p was exacerbated by the short duration of the water balance tests (5-10 days) and the large difference in the energy balances of the lagoon and the pan. The problems associated with evaporation pans are well documented in the literature. In the lagoon application, these limitations seem to be even more pronounced. The large temporal and site-to-site variation in k_p would make it very difficult to predict E from lagoons using evaporation pans. The uncertainly in E would cause large errors in the calculation of S , negating any utility in the approach. Data suggest that the bulk transfer approach of Ham (1999) is the best approach for measuring E from lagoons. Research is underway to streamline the equipment required for this method, and devise a protocol for its use by state agencies and consultants. Figure 3 shows the data acquisition system, meteorological raft, and water level recorder required to use this technique.

References

Ham, J.M. (1999) “Estimating evaporation and seepage from lagoons used to contain animal waste.” *Trans. ASAE*: 42:1303-1312.

Ham, J.M., and DeSutter, T.M. (1999). “Seepage losses and nitrogen export from swine waste lagoons: A water balance study.” *J. Environ. Qual.* 28:1090-1099.

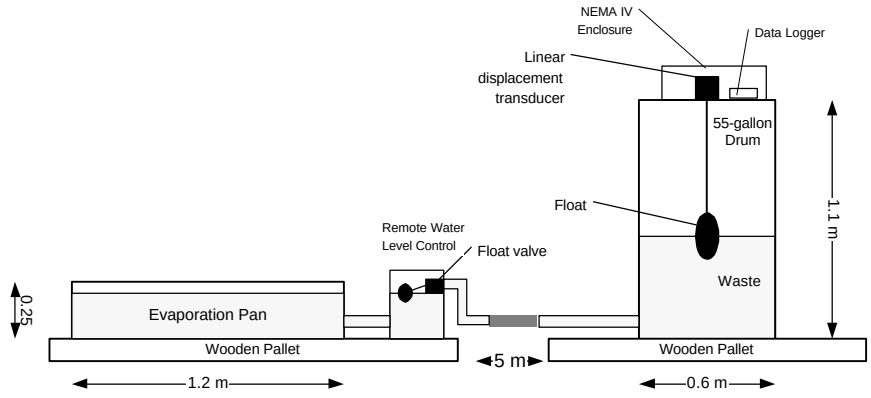

Figure 1. Diagram of the portable Class-A pan system for use at lagoons.

Figure 2. Photograph of the evaporation pan system in the field.

Figure 3. Photograph of the equipment required to implement the bulk transfer approach of Ham (1999).

Information Transfer Program

One of the goals of KWRRI is to communicate information on water resources in Kansas. Our targeted audiences include the scientific community, other state and federal agencies, the agricultural community, and the general public. Our primary information transfer activities include the following:

1) Water and the Future of Kansas Conference - We sponsor an annual conference that brings together scientists, agency personnel, agricultural interests, and other water resources professionals. Last year the conference was held in Manhattan, in March. Attendance was about 200 people. The theme was "Water Quality Restoration and Protection". The program included plenary presentations on hypoxia, the TMDL process in Kansas, voluntary compliance approaches to meeting water quality goals, and citizen invovlement in water quality monitoring. Breakout sessions were on water quality, local involvement and action, and recent research reports.

2) Quarterly newsletter - KCARE produces a quarterly newsletter with information from KWRRI.

3) Special Seminars and Tours - We sponsor special seminars or tours on water topics. This past year we hosted a water quality tour in the Wichita, KS area.

4) Special Reports - We produce special reports from time to time. Last year, we produced a report on the effectiveness of lagoons in containing animal waste.

Basic Information

Title:	A Field Assessment of Direct-Push Technology for Site Characterization Investigations
Start Date:	3/1/2000
End Date:	2/28/2001
Descriptors:	
Lead Institute:	University of Kansas
Principal Investigators:	James J. Butler, Li Zheng

Publication

INFORMATION TRANSFER

Results were presented at three national meetings (American Geophysical Union, Spring 2000, Washington; Geological Society of America, Nov. 2000, Reno; National Ground Water Association 2000 Petroleum Hydrocarbons and Organic Chemicals in Ground Water Conference, Nov. 2000, Los Angeles) and two workshops (Midwest Geosciences Group workshop at the University of Texas at Arlington, June 2000; Advances in Site Characterization for Environmental and Engineering Projects at Glaciated Sites Workshop, Minneapolis, October 2000). Results were also presented to the Kansas water resources community at the 18th Annual Water and the Future of Kansas Conference in Manhattan (March 2001) and at two presentations to personnel of the Division of Water Resources of the Kansas State Department of Agriculture in Topeka.

Two web sites were set up at the Kansas Geological Survey (www.kgs.ukans.edu/Hydro /DirectPush/index.html and www.kgs.ukans.edu/Hydro/WellTests/index.html) for rapid dissemination of the results of this project. Reports and a spreadsheet for analysis of slug tests can be downloaded from these sites.

USGS Summer Intern Program

Student Support

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

Notable Awards and Achievements

None at this time.

Publications from Prior Projects

1. None at this time.