Kansas Water Resources Research Institute

Annual Technical Report

FY 1999

Introduction

Research Program

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Sources and Control of Geosmin in Midwestern Water Supply Reservoirs
Project Number	B-02
Start Date	09/01/1998
End Date	02/28/2001
Research Category	Water Quality
Focus Category #1	Water Supply
Focus Category #2	Water Quality
Focus Category #3	Treatment
Lead Institution	University of Kansas

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Stephen J. Randtke	Professor	University of Kansas	01
Frank deNoyelles	Professor	University of Kansas	01
David W. Graham	Professor	University of Kansas	02

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 water as the primary indicators of its safety. In recent years, Midwestern water utilities have been facing increasing taste and odor problems, some of which have been quite severe. A number of utilities have found it necessary to spend large sums of money for taste and odor control; and their efforts have not always been successful.

In the majority of cases, geosmin has been found to be, or is suspected of being, the primary culprit; but information regarding the sources of geosmin in Midwestern reservoirs, and the factors influencing its production, release, and decay, are lacking. There is also a lack information regarding the effectiveness of in-lake management techniques for controlling geosmin in Midwestern reservoirs, as well as the effectiveness of drinking water treatment processes when extremely high levels of geosmin, e.g., 200 to 500 nanograms per liter (ng/L) are encountered. The goal of this project is to help managers of water supply reservoirs, treatment plant superintendents, and others to control geosmin and related compounds in Midwestern drinking water supplies. Specific objectives include: 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.

Methodology

The project objectives are being pursued through an integrated combination of field sampling, mesocosm experiments, and laboratory experiments. An integrated approach is required to understand geosmin production and decay, which result from complex interactions among physical, chemical, and biological phenomena, and to develop effective in-lake control methods. In-plant treatment options can, for the most part, be adequately assessed using simple laboratory tests, although pilot studies may be required to provide adequate assurance of full-scale applicability. Several reservoirs with a history of taste and odor problems, as well as water treatment facilities drawing water from these reservoirs, are being routinely monitored for geosmin in an effort to monitor the seasonal occurrence of geosmin in various Midwestern reservoirs, to detect the onset of geosmin episodes (so that additional studies focusing on the nature of geosmin episodes can be initiated), and to examine the effectiveness of current treatment practices for removing geosmin. Whenever possible, sampling is coordinated with other water quality investigations so that more robust sets of water quality data can be developed (as well as 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 have not yet experienced any major taste and odor episodes during the study; and, based on results to date, it appears that the occurrence of geosmin is primarily related to larger-scale phenomena. Accordingly, field sampling efforts have been redirected toward examining the temporal and spatial variability of geosmin on a broader scale, e.g., riverine versus lacustrine environments, and as a function of 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, are being used to examine geosmin production, release, and decay under more controlled conditions and to examine the effective of selected in-lake management techniques for geosmin control. Laboratory experiments are being conducted: 1) to obtain a deeper (i.e., mechanistic) understanding of phenomena observed in the field and in mesocosm experiments; and 2) to examine potentially useful treatment techniques on a small scale, especially techniques that are potentially applicable to severe episodes. 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 are now deemed to be premature, and are being replaced with additional mesocosm and laboratory experiments designed to

provide a deeper understanding of geosmin production and decay; and other pilot studies, particularly those focused on treatment, are awaiting the occurrence of a significant episode.

Principal Findings and Significance

The following paragraphs describe: the tasks that have been accomplished since the project began in September, 1998; the principal findings, to date, and their significance; and future plans. Samples for geosmin analysis have been collected from five lakes (including four major federal reservoirs in three different states, as well as a small experimental lake), three tributaries to one lake, and three drinking water treatment plants able to partially remove geosmin. Although detectable levels of geosmin have been found in most samples, no severe episodes have occurred and no microenvironment samplings have been conducted. Despite the lack of severe episodes, the data are nevertheless quite useful. Samples collected from different depths at two lakes clearly show that the geosmin levels are not always uniformly distributed, yielding important clues as to the sources and behavior of the geosmin. In combination with previously acquired geosmin data and various historical records, these data are expected to prove useful in understanding the conditions leading to geosmin production and, ultimately, the causes of more severe geosmin episodes. Data for Clinton Lake show a distinct pattern of higher levels of both cyanobacteria and geosmin in the transitional areas of the reservoir than in the riverine areas or main basins. Similar patterns are being explored in a study of Cheney Reservoir being jointly conducted with another project team. The data for Cheney Reservoir show an unexpectedly strong correlation between chlorophyll-a and geosmin; and this relationship will be further examined this coming summer and fall. The possibility of adding several additional lakes to the study this summer, in cooperation with the Kansas Biological Survey, is being actively pursued. In May, 1999, two of the principal investigators made a two-day trip to visit three other lakes (in Oklahoma) that are used as sources of drinking water by a utility experiencing severe periodic taste and odor problems. The investigators met with the water plant superintendents, the lake managers, and other personnel to discuss their experiences in depth and to explore the possibility of participating in a joint project. However, to date, no agreement has been reached, and any project that emerges at this late date is unlikely to be strongly tied to the current project. A mesocosm study involving 32 large (10 m3) tanks was conducted in the fall of 1998 to examine the impact of various loadings of nitrogen and phosphorus on geosmin production. Geosmin production was negligible in all of the tanks, despite the presence of large populations of cyanobacteria in many of the tanks, clearly indicating that geosmin production is not simply the result of nutrient enrichment or of a particular nitrogen to phosphorus ratio. A similar experiment, using ponds (which are much larger than the tanks and have much more sediment on the bottom) and designed to explore this aspect in greater detail, began earlier this month. Many laboratory studies have been completed, while others are on-going or will be undertaken this summer and fall. One series of laboratory-scale tests examined the rate of degradation of dissolved and intracellular geosmin under aerobic and anaerobic conditions and in both light and dark conditions. Both commercially available geosmin and geosmin extracted from natural sources were used in these studies, since biodegradation rates may vary with the isomeric form present. Dissolved geosmin was found to degrade relatively rapidly (in several days), whereas the degradation rate of intracellular geosmin was substantially slower. In other experiments, both temperature and water quality were found to strongly influence the rate of biodegradation of geosmin; and additional studies are being conducted in an effort to identify the water quality parameters influencing geosmin degradation. This information will be helpful in identifying conditions conducive to geosmin production and decay and may possible suggest practical means for controlling severe episodes. An on-going series of experiments is examining the interaction between cyanobacteria and actinomycetes under both light and dark conditions; and, as part of this experiment, a technique was developed for determining geosmin and MIB using small samples of bacterial cultures. The results to date are difficult to interpret, but the investigators are optimistic that

additional results will clarify the relationship between these two important groups of organisms. An experiment was conducted during April and May of 1999 to examine the influence of nutrient concentrations and substrate composition on the production of geosmin by bacteria. The results of this study are currently being compiled and reviewed and will serve as the basis for additional studies this summer and fall. Jar tests were conducted to examine the rate and extent of geosmin removal by seven different types of powdered activated carbon (PAC). Additional tests examined the effect of adding various chemicals (potassium permanganate, lime, polymers, chlorine, and chlorine dioxide) before or after the PAC was added. There were significant differences among the types of PAC in both the rate and extent of geosmin adsorption; and all of the chemicals except lime significantly interfered with geosmin removal, whether they were added before or after the PAC. Another experiment examined the use of split dosing of PAC, i.e., dividing the dosage in half and treating the water twice, a practice that is often possible in a water treatment plant and that has been used at times by one of the treatment plants participating in the study. The results were disappointing, in that split dosing did not appear to offer much of an advantage over the use of a single dosage. In a subsequent experiment, the investigators simulated the addition of PAC to a floc-blanket clarifier used for lime softening. The results indicated that the PAC was much more effective in this operating mode; and additional experiments to examine the practicality of this approach for utilities practicing lime softening are planned for this summer. Water utilities faced with severe taste and odor problems often consider using granular activated carbon (GAC) to address the problem. However, as demonstrated by the results of this and other studies, the GAC filters typically used in water treatment plants have a relatively short detention time and are able to remove only a fraction (usually less than half) of the geosmin present in the water being treated. Therefore, GAC must be combined with other processes (e.g., PAC or oxidative processes) to adequately control the problem. To more thoroughly investigate the use of GAC, the investigators collaborated with a local water utility to design and build four pilot columns suitable for studying GAC adsorption. These will be used to conduct pilot studies during the next taste and odor episode this utility experiences. The results of a series of experiments employing a recently developed synthetic zeolite indicate that it removes geosmin much more effectively than PAC. Additional experiments are being performed to more closely examine the behavior of this particular adsorbent, as well as factors influencing its performance; and the practicality and cost effectiveness of full-scale use of this adsorbent are being evaluated. The potential of other adsorbents (adsorbents not typically used in drinking water treatment plants) to effectively remove geosmin is also being evaluated; and additional laboratory studies to quantify the performance of novel adsorbents will be conducted this summer if they appear to be warranted. Other (non-adsorptive) technologies, suitable for either in-plant and in-lake use in controlling geosmin, are also under active investigation.

Descriptors

Geosmin, taste and odor, algae, cyanobacteria, actinomycete management, water quality control, water treatment

Articles in Refereed Scientific Journals

None at this time.

Book Chapters

None at this time.

Dissertations

None at this time.

Water Resources Research Institute Reports

Hargrove, William, 1999, Kansas Water Resources Research Institute Annual Report, Kansas State University, Manhattan, KS

Conference Proceedings

deNoyelles, F., S. H. Wang, J. O. Meyer, D. G. Huggins, J. T. Lennon, W. S. Kolln, and S. J. Randtke, "Water Quality Issues in Reservoirs: Some Considerations From a Study of a Large Reservoir in Kansas," Proceedings of the 49th Annual Environmental Engineering Conference, University of Kansas, Lawrence, KS, February 3, 1999.

Other Publications

None at this time.

Basic Project Information

Basic Project Information	
Category	**Data**
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	03/01/1999
End Date	02/28/2001
Research Category	Water Quality
Focus Category #1	Surface Water
Focus Category #2	Nutrients
Focus Category #3	Non Point Pollution
Lead Institution	Kansas State University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Gary M. Pierzynski	Associate Professor	Kansas State University	01
Gary Clark	Professor	Kansas State University	02

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. 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 twenty-four hours after pre-irrigation. The rainfall simulator applied water at 75 mm/h until runoff occurred for thirty minutes. Runoff from each plot was divided into that occurring from 0 to 10 minutes, 10 to 20 minutes, and 20 to 30 minutes. All runoff occurring in each 10 minute period was collected in 5 gallon buckets, weighed to determine runoff volume, and sub-sampled for analysis. Water samples were stored at 4oC until analysis. Sediment concentrations in water samples were determined by passing a known volume of water through a pre-weighed 0.45 µm filter. The filter and sediment were be dried to a constant weight at 105oC 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 be 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

Construction of the rainfall simulator was successfully completed during the summer of 1999. Trial runs with the simulator indicated that the uniformity of application within the plot areas was acceptable as determined by a coefficient of variation of less than 20% for water depth in containers placed in a grid pattern underneath the simulator. Site selection was also successful. Two areas at the North Agronomy Farm were found with different soil textures and organic C contents in the surface horizons. The north site had a silty clay loam texture while the south site had a loam texture. Soil series will be determined at a later date. The manure that was applied contained an average P concentration of 0.38%. Manure applications ranged from 0 to 200 Mg/ha so P applications ranged from 0 to 760 kg/ha. Field data are presented from the first rainfall simulation. Data from the second rainfall simulation are not yet available. Runoff volume generally decreased as the amount of manure applied increase (Table1) The organic C additions with the manure likely increased the infiltration capacity of the soil. This effect was more pronounced on the north site where soil organic C levels were lower (data not shown). Total P concentrations in runoff were significantly higher with 150 or 200 Mg/ha of manure compared to all other levels of manure addition. It was expected that the total P levels in runoff would increase dramatically as the amount of manure added increased. However, 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. Soluble and bioavailable P concentrations increased significantly as the amount of manure added increased. Table 1. Runoff characteristics from the south plots of the manure-runoff study. Soluble P concentrations at the south site reached 1.1 mg/L while at the north site the maximum levels were 0.62 mg/L, suggesting that soil and site characteristics strongly influence soluble P levels in runoff. Bray-1 extractable P concentrations were increased to nearly 500 mg/kg at both sites by the addition of manure. There was a significant linear relationship between Bray-1 extractable P in soils and soluble P concentrations in runoff at the south site (Figure 1). A similar relationship was found for the north site, although the slope of the regression line was lower, reflecting the lower soluble P levels. Several more rainfall simulations will be performed in 2000. The effect of time on runoff characteristics and soil test P levels is of interest. As crop growth occurs, the influence of crop P removal and crop residue on runoff characteristics will be evaluated. Figure 1. Correlation between Bray-1 extractable P levels and soluble P concentrations in runoff from the south site.

Descriptors

Phosphorus, soil-water relationships, water quality, best management practices.

Articles in Refereed Scientific Journals

None at this time.

Book Chapters

None at this time.

Dissertations

None at this time.

Water Resources Research Institute Reports

Hargrove, William L., 1999, Kansas Water Resources Research Institute Annual Report, Kansas State University, Manhattan, KS

Conference Proceedings

None at this time.

Other Publications

None at this time.

Basic Project Information

Basic Project Information	
Category	**Data**
Title	The Kansas Water Institutue:colon; An Integrated Electronic Community of Knowledge
Project Number	E-01
Start Date	03/01/1999
End Date	02/28/2001
Research Category	Water Quality
Focus Category #1	Education
Focus Category #2	None
Focus Category #3	None
Lead Institution	University of Kansas

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Robert Worth Buddemeier	Professional Staff	University of Kansas	01
James K Koelliker	Professor	Kansas State University	02
Edward A. Martinko	Professional Staff	University of Kansas	03
William L. Hargrove	Professional Staff	Kansas State University	04

William L. Hargrove	Professional Staff	Kansas State University	04
Gary Clark	Professor	Kansas State University	05

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: Two parallel prototype sites have been established; http://www.vkwri.org, hosted by Kansas State University, and http://www.kgs.ukans.edu/KWRC/vkwri/, based at the Kansas Geological Survey. The rationale for parallel sites in the early phases of development is: Experience showed that system security measures made it difficult to grant the necessary degree of access to outsiders from either system, making local site managers bottlenecks for relayed modifications, and slowing review and response times. It became apparent that there is a role to be played by both simple, robust, relatively low-tech presentations (to serve those with slow connections and relatively little internet experience), and a more fully developed set of pages that take advantage of the latest in browser and server technologies. Until the appropriate combination or compromise can be identified on the basis of experience, it was judged imprudent to forego either option; the KSU site has pursued the high-tech approach; the KGS site has followed the "plain Jane" path. Contacts and information links at the two institutions are sufficiently different that some degree of specialization in developing content appears efficient, with combination or linking achieved as the project matures. The sites 'went public' with a poster and live display at the Water and Future of Kansas Conference in March 2000, and since then have continued to develop and to seek feedback from the Kansas water community. A framework of basic information categories, information pages, and links is in place, and a growing inventory of interactive tools is being implemented (feedback and discussion links, registration capabilites, search engines, interactive calendars, etc.). Targeted audiences are being progressively identified, provided with specific interest pages and links, and contacted by e-mail to solicit feedback and participation. Science educators and researchers at institutions of higher education have been in the first cohort addressed; other groups and disciplines will follow. Responses have been positive, and the variations are being carefully analyzed. Among the most enthusiastic responders have been managers of water districts, who have a need for and appreciation of

information resources, but lack the information infrastructue and access found in larger agencies and metropolitan areas. Additional funding has been found which will keep the KGS web designer employed and available beyond the part-year funding provided by the current grant, and potentially beyond the project year. This provides the time necessary to systematically work through the developmental processes and establish the sites as functional tools for the water community. Present schedule plans are to complete the structural development phase and initial notifications by the end of summer, devoting the final six months of the project year to integration and development, with a growing focus on contributions to definition and discussion of current water issues.

Descriptors

Water Resources, Information Systems, World Wide Web, Collaboration

Articles in Refereed Scientific Journals

None at this time.

Book Chapters

None at this time.

Dissertations

None at this time.

Water Resources Research Institute Reports

Hargrove, William L., 1999, Kansas Water Resources Research Institute Annual Report, Kansas State University, Manhattan, KS.

Conference Proceedings

None at this time.

Other Publications

None at this time.

Information Transfer Program

Basic Project Information

Basic Project Information	
Category	**Data**
Title	16th Annual Water and the Future of Kansas Conference
Description	Protecting Water While Utilizing Waste
Start Date	03/01/1999
End Date	02/28/2000
Type	Conferences
Lead Institution	Kansas State University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
William L. Hargrove	Professional Staff	Kansas State University	01

Problem and Research Objectives

Methodology

The most significant information transfer activity sponsored by KWRRI was the Water and Future of Kansas Conference. This conference is a statewide conference held to present current information and to discuss current issues in water resources in our state. In March, 1999, approximately 170 people attended representing a crossection of regulatory agency, university, private consulting engineers, and agribusiness personnel.

Principal Findings and Significance

Articles in Refereed Scientific Journals

None.

Book Chapters

None

Dissertations

None

Water Resources Research Institute Reports

Hargrove, William L., 1999, Kansas Water Resources Research Institute Annual Report, Kansas State University, Manhattan, KS.

Conference Proceedings

Protection Water While Utilizing Waste, 16th Annual Water and the Future of Kansas Conference Proceedings.

Other Publications

None

USGS Internship Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	N/A	2	5	N/A	7
Masters	N/A	2	N/A	N/A	2
Ph.D.	N/A	1	N/A	N/A	1
Post-Doc.	N/A	N/A	N/A	N/A	N/A
Total	N/A	5	5	N/A	10

Awards & Achievements

None at this time.

Publications from Prior Projects

Articles in Refereed Scientific Journals

Kimmell, R.J., G.M. Pierzynski, K.A. Janssen, and P.A. Barnes. 2000. Effects of tillage and phosphorus placement on phosphorus runoff losses. J. Environ. Qual. (Submitted).

Book Chapters

Dissertations

Kimmell, R.J. 1999. Comparison of tillage and fertilizer application methods for control of phosphorus losses in runoff water. M.S. Thesis, Kansas State University. 124 pp.

Water Resources Research Institute Reports

1998 Kansas Water Resources Research Institute Annual Report

Conference Proceedings

Other Publications