Water Resources Research Institute

Annual Technical Report

FY 1999

Introduction

The most important educational task we face these days is ensuring the success of future generations. The second task then becomes leaving a legacy of a quality of life we all would like to see for the future. Environmental research and education offers us the opportunity to accomplish both of these at the same time. To be effective, environmental research and education must be factual, balanced, and focused on helping the general public understand the scientific concepts which impact environmental issues. These programs should increase environmental awareness, promote knowledge of environmental concepts, develop basic environmental skills, and promote personal responsibility and stewardship. In the end, environmental research and education boils down to one simple yet profoundly important imperative: preparing ourselves for life and all its surprises in the next century. When the next century rolls around, it will not be enough for a few individuals to know what is going on while the rest of us wander around in total ignorance. The Alabama Water Resources Research Institute (AWRRI) serves to focus the talents of university faculty in our state on priority problems in water resources and activities affecting those resources. This report, with the descriptions of each Section 104(b) research project supported in the Institute program, illustrates the broad range of problems and the variety of talent available in the state's universities to work on solutions of these problems. The Institute has continued its historical commitment to the involvement of students (graduate and undergraduate) in research projects. Thus, the activities supported through the AWRRI not only provide valuable scientific information but also help to produce the future scientists and leaders so necessary to the development of this region. This report briefly describes the three projects supported with funds provided by the U.S. Geological Survey during the past year.

Research Program

Basic Project Information

Basic Project Information	
Category	**Data**
Title	COST-EFFECTIVE STRATEGIES FOR MINIMIZING WATER USAGE AND DISCHARGE IN THE POLYMER AND FIBER INDUSTRIES
Project Number	98-02
Start Date	09/01/1998
End Date	08/31/2000
Research Category	Engineering
Focus	Management and Planning

Category #1	
Focus Category #2	Groundwater
Focus Category #3	Surface Water
Lead Institution	Auburn University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Mahmoud M. El-Halwagi	Associate Professor	Auburn University	01
Gopal Krishnagopalan	Professor	Auburn University	01

Problem and Research Objectives

The fiber (pulp, paper, and textile) and polymer industries are the primary processing facilities in the Southeast. In addition to providing tremendous economic impact on the region, they also result in a major ecological impact because of their high levels of fresh water usage and wastewater discharge into our rivers and aquatic resources. In light of the escalating stringency in environmental regulations on the discharge of wastewater from processing facilities and the consistent calls for "zero discharge" targets, the fiber and polymer industries are facing a significant challenge of maintaining economic competitiveness while becoming more environmentally benign. Therefore, it is acknowledged that a critical need for the industry is to have design and operational strategies that can address economic and environmental issues simultaneously. The objective of this research is to develop comprehensive, cost-effective design and operating schemes that target the optimization of water usage, recycling, and discharge in the fiber and polymer industries. Mass-integration methodology has been employed as a systematic framework for identifying optimal solutions to the above-mentioned targets. This integrated approach will not only help the fiber and polymer industires meet environmental regulations for water usage and discharge but will also create an excellent potential for economic gain for the processing facilities in the Southeast. These economic benefits will accrue as a result of optimizing the usage of water resources, minimizing wastewater treatment costs (it is estimated that water usage and treatment cost $1 - $10/ton of fiber product and $5 - $25/ton of polymer produced), maximizing the recovery of valuable materials and debottlenecking the process.

Methodology

The research sponsored by the U.S. Geological Survey has been matched with cost sharing from General Electric Plastics (in Burkville, AL), M. W. Kellogg (in Houston, TX), U. S. Alliance (in Coosa Pines, AL), the Pulp and Paper Research and Education Center (Auburn University), and the National Council for Air and Stream Improvement (NCASI) for the pulp and paper industry (the most prestigious industry-sponsored council on environmental research for the pulp and paper industry). In addition to cost sharing from these organizations, we have gained unique access to their process data and expertise that are critical in establishing credible and applicable research. We have merged our fundamental pollution-prevention and optimization research with practical insights from industry. The result was the development of comprehensive, cost-effective design and operating schemes that

targeted the optimization of water usage, recycling, and discharge in two major industries: the polymer industry and pulp and paper industry. Mass-integration methodology was employed as a systematic framework for identifying optimal solutions to the above mentioned targets. In order to get feedback on the applicability of the devised methods, we have applied these techniques jointly with three companies: General Electric Plastics, M. W. Kellogg, and U. S. Alliance

Principal Findings and Significance

The results of these studies indicate that our integrated approach can indeed help the fiber and polymer industries meet environmental regulations for water usage and discharge and also create an excellent potential for economic gain for the processing facilities in the Southeast. Furthermore, with the help of NCASI, we are in the process of developing a tutorial on optimizing water usage and discharge in a "generis" pulp and paper mill where data and findings can be shared with a large number of individuals from industry without compromising the confidentiality of actual industrial processes. Because of the comprehensive nature of our approach, it can be generally applicable to a wide variety of Southeastern fiber and polymer plants. Short-term impact will be in the form of cost-effective implementable solutions to the water problems of the industry. Long-term impact will be in the form of proposed technology changes and best technology based management practices for the Twenty First Century. The research has also identified priority research needs that should be carried out by research organizations as well as the industry. Four major benefits are gained from this research project: 1. Ecological: A typical pulp and paper mill uses 40 - 70 tons of fresh water per ton of product. Our research has identified sustainable strategies to reduce such usage by 30 - 50%. Because of the tremendous amounts of fresh water used and wastewater discharged by these, the project findings can lead to significant impact on the quality of water resources. Furthermore, the reduction in chemical content of these discharges will positively influence the public health and quality of life in the Southeast. 2. Economic: Economic indicators were included as a strong element in our research. The usage of advanced optimization techniques insured that cost of proposed strategies is minimized. The research findings have identified pollution prevention strategies that cost less than 55% of the current treatment costs. As a result of the decreased usage of water, the reduced cost of treating terminal wastewater streams, and the less energy required to process water within the processing facilities, the recovery of valuable chemicals from in-plant water streams, and the sustainable ability to cope with tightening environmental regulations, the findings of this project can foster the ability of the processing facilities to manitain their international competitiveness and can significantly decrease the prospects of these plants to close or move to other countries with lower wages and less emphasis on the environment. 3. Technical: Our research has been undertaken in consultation with key personnel within the leading fiber and polymer industries in the Southeast and NCASI. Our results have been continuously communicated with sponsoring plants. Furthermore, our "generic" mill research sponsored by NCASI will be shared with the rest of industry and academia. Our research findings have also been successfully implemented within several of these sponsoring facilities. Therefore, the methodologies developed from this project can be of significant technical value to the American industry. 4. Educational: We have also incorporated the research findings into our educational activities. Case studies and methods developed in this research were taught to senior Chemical Engineering students at Auburn University (courses ChE 447 & 546). Furthermore, we have presented simplified versions of our work to students at Cary Woods Elementary School in Auburn, Alabama.

Descriptors

Industrial Wastewater, Economics, Wastewater Treatment, Water Demand, Water Quality, Water Reuse, Water Treatment.

Articles in Refereed Scientific Journals

Parthasarathy, G. and M. M. El-Halwagi, 2000, "Optimum Mass Integration Strategies for Condensation and Allocation of Multicomponent VOCs", Chem. Eng. Sci., 55, 881-895. Shelley, M. D. and M. M. El-Halwagi, 2000, "Componentless design of Recovery and Allocation Systems: A Functionality-Based Clustering Approach", Comp. Chem. Eng. (in press). Noureldin, M. B. and M. M. El-Halwagi, 200, "Pollution-Prevention Targets through Integrated Design and Operation", Com. Chem. Eng. (in press). Noureldin, M. B. and M. M. El-Halwagi, 1999, "Interval-Based Targeting for Pollution Prevention via Mass Integration", Com. Chem. Eng., 23, 1527-1543.

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Lovelady, E. M., G. Parthasarathy, A. Hamad, G. Krishnagopalan, and M. M. El-Halwagi, 1998, "Cost-effective Pollution Prevention in the Pulp and Paper Industry Via Mass Integration", proceedings of the Topical Conference on Pollution Prevention and Environmental Risk Reduction, Ed.: Y. Cohen, AIChE, NY, pp. 661-667.

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	A Preliminary Evaluation Of The Effectiveness Of Current BMPs In Controlling Stormwater Discharges From Small Construction Sites In The Valley And Ridge Physiographic Region And Developing Metrics To Assess The Effects Of Discharge On Stream Communities
Project Number	99-02
Start Date	03/01/1999
End Date	02/29/2000
Research Category	Water Quality
Focus Category #1	Water Quality
Focus Category #2	Sediments
Focus Category #3	Ecology

Lead Institution	Auburn University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Ken R. Marion	Professor	University of Alabama at Birmingham	01
Robert Angus	Professor	University of Alabama at Birmingham	02
Melinda M. Lalor	Assistant Professor	University of Alabama at Birmingham	03

Problem and Research Objectives

As population expansion and increasing development occur in the Southeast, stormwater runoff from construction sites has become an increasingly major contributor to siltation input into our streams and rivers. While large construction projects represent single major potential pollution sources and are usually more visible, small construction sites (usually future home sites <5 acres) are both more numerous and are less likely to employ adequate erosion control best management practices (BMPs). By far the most common BMPs employed at such sites are plastic silt fences and hay bales. Although factors controlling erosion processes are well known, few scientific studies have been performed to evaluate the effectiveness (or lack of it) in the field of such BMPs, especially as affected by physical site and rainfall characteristics. This is especially true for the more upland and hilly terrian of Alabama and the Southeast. Information on the effectiveness of such BMPs in hilly terrain situations and the factors influencing the effectiveness is needed to assist in the selection of appropriate BMPs and the design of future erosion controls. Such information would be directly useful to federal, state and local regulatory agencies charged with the protection of aquatic environments. Additionally, in order to adequately evaluate the effectiveness of silt fence erosion control, assessments of the runoff on receiving streams or drainages are needed. Although a number of bioassessment metrics are available and commonly used, some metrics are more responsive to some stressors than others and are known to vary between physiographic regions. There is a critical need to develop or refine such metrics so that they are more sensitive biocriteria from which a more refined discrimination can be made between the level of impairment between sites. Such improved metrics will assist in the selection and design of improved erosion control devices. The major objectives of this research are (1) to assess the effectiveness of silt fences in controlling sedimentation runoff during heavy rainfall events in hilly terrain areas of the southeast, and (2) to develop or refine biological metrics that are sensitive indicators of siltation impacts on aquatic communities.

Methodology

The study sites are in the upper reaches of the Cahaba River basin in north central Alabama. The effectiveness of in-place erosion control devices (silt fences) is being evaluated at small construction sites. Stormwater runoff samples were collected to investigate the relationship between the quality and quantity of the runoff and physical site characteristics. Stormwater runoff samples escaping from silt fences were collected during "intense" (>1inch/hr) rain events. The runoff samples have been analyzed at the UAB Environmental Engineering Laboratory for turbidity (using a nephelometer), particle size distribution (using a Coulter counter), and total solids (dissolved solids and suspended solids, using methods 2540B and 2540C in Standard Methods for Examination of Water and Wastewater; NSTM,

1998). These data have been entered into a computer database for statistical analysis. Six tributary or upper mainstream sites have been studied to investigate the effects of sedimentation input from upstream construction sites on both habitat quality and the biological "health" of the aquatic ecosystem (using benthic macroinvertebrates and fish). Two of the sites have a heavy sediment load, two have been moderately impacted, and two (reference sites) have had little or no sediment input. Each site was assessed in the spring, after the period of winter rains (to evaluate immediate effects), and again the following late summer or early fall (to evaluate delayed effects). An evaluation of habitat quality is an important component of the assessment of the ecological integrity of a site. We have used EPA-recommended procedures for high gradient streams, as outlined in the "Revision to Rapid Bioassessment Protocols for Use in Streams and Rivers" to assess the habitat quality at our study sites. This procedure quantifies the degree of impaction at each site and permits the making of comparisions between sites.

Principal Findings and Significance

EFFECTIVENESS OF SILT FENCES - Silt fences (in good condition) were somewhat effective in reducing the amount of silt in runoff, at least as compared to no management practice at all. A significant reduction ($p < 0.05$, Mann-Whitney U test) was seen in numbers of small (<5 µm) and total particles per ml. Reductions were seen for numbers of large (<5 µm) particles, turbidity (NTU) and total suspended solids. These differences were not quite as great, but would be significant at $a = 0.10$. In contrast, for every variable measured, the values of samples taken below silt fences were significantly higher ($p < 0.001$) than samples collected from vegetated control sites. Thus, silt fences are only partially effective at preventing the runoff of silt. Surprisingly, the amount of silt in runoff (as measured with the variables mentioned above) was not significantly correlated with slope of the site, amount or intensity of rainfall. However, continued studies this year that concentrate on manipulated sub-plots within one large experimental area will provide more opportunities to explore possible correlations with site and rainfall characteristics. Development of Biological Metrics Sensitive to Sedimentation Effects FISH- Preliminary analysis of the fish biota indicates that various metrics used to evaluate the biological integrity of the fish community (IBI) are altered in the most sedimented streams (Shades and Patton Creeks). In these streams the proportion and biomass of darters is lower (or nonexistent), the proportion and biomass of sunfish is higher, the Shannon-Weiner diversity index is lower, and the number of tolerant species higher. The trends are most clear when the two most sediment-impacted streams (Shades and Patton) are compared to the least sediment-impacted stream (upper Cahaba at Hewitt-Trussville High School). These streams also show the most contrast in overall habitat assessment scores via EPA Rapid Bioassessment Protocol. Correlations with degree of sedimentation impacts are less clear when all six of our sampling streams are factored in. Pinchgut, Little Cahaba Creek and Cahaba Valley Creek vary widely in both fish metrics and sediment depth and impact and show little obvious correlations. Additional data from this year (2000) and concentrating on just the two best and worst sediment-impacted streams should strengthen and clarify our results. BENTHIC MACROINVERTEBRATES- Several macroinvertebrate metrics (Sorenson's Community Similarity index, Shannon-Weiner diversity index, EPT index, % chironomids, Jaccard Coefficient, and Hilsenhoff Biotic index) reach their highest or lowest point in the two streams with the most sediment load. Although Spearman Rank Correlations of each of these metrics for all streams studied with several measures of sedimentation load show few statistically significant relationships at the 0.05 level, p values approach this level, indicating definite trends. The EPT index (number of mayfly, stonefly and caddis fly genera) and the Hilsenhoff Biotic index (HBI) show the most promise as indicator metrics most sensitive to sedimentation. HBI is positively correlated to the percent drainage alteration ($p=0.065$), sediment depth ($p=0.09$), and stream bottom percent cover by sand and silt ($p=0.069$). The EPT index is positively correlated to percent drainage alteration ($p=0.004$), sediment depth ($p=0.062$),

and percent cover by sand and silt (p=0.011). This year's concentration on the two best and worst sediment-impacted streams should produce further clarification of the promise of these indices.

Descriptors

Erosion, Erosion Control, Construction, Sediments, Fish Communities, Invertebrate Communities, Bioassessment.

Articles in Refereed Scientific Journals

Corn, Elizabeth, Robert Angus, and Ken Marion. 2000. A bioassessment of tributaries in an increasingly urbanized watershed. Association of Southeastern Biologists Bulletin 47(2): l03. (abstract; poster presented at ASB annual meeting in Chattanooga, TN, April, 2000). Corn, E., R. Angus, and K. Marion. 1999. Benthic macroinvertebrate community indices in tributaries of the Cahaba River in Alabama: Effects of urbanization. Association of Southeastern Biologists Bulletin 46 (2): l06-107. (abstract; poster presented at ASB annual meeting in Wilmington, NC, April, 1999; data from one sampling period under grant support used). Corn, Elizabeth, Robert Angus, and Ken Marion. 1999. Variability in macroinvertebrate indices in urbanized streams tributary to the Cahaba River near Birmingham, Alabama. The Journal of the Alabama Academy of Science 70(l-2): 15. (abstract; paper presented at AAS annual meeting in Athens, AL, April, l999; data from one sampling period under grant support used).

Book Chapters

Dissertations

Corn, Francis Elizabeth. 2000. A Bioassessment of Seven Tributaries of the Upper Cahaba River Using Benthic Macroinvertebrate Populations. M.S. Thesis, University of Alabama at Birmingham. 131 pp.

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	THE EFFICACY OF EMPLOYING BACILLUS GLOBIGII AS A PARTICULATE TRACER IN AQUATIC SYSTEMS
Project Number	99-03
Start Date	03/01/1999
End Date	02/29/2000
Research	

Research Category	Water Quality
Focus Category #1	Groundwater
Focus Category #2	Surface Water
Focus Category #3	Water Quality
Lead Institution	Auburn University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Clifford R. Lange	Associate Professor	Auburn University	01

Problem and Research Objectives

Very few aqueous environmental processes occur in a static environment. Rather, most aqueous reactions occur in systems where there is some type of flow. Thus, characterization of the flow and transport regime is essential to understanding each environmental system. This holds true for both natural and engineered surface and subsurface systems. Tracer studies are employed to identify and quantify the flow regime of environmental systems. An ideal tracer is a non-reactive substance which has similar properties to the carrier fluid which is being studied (i.e., water) or the compound being transported (i.e., particulates). A tracer should be easy to distinguish from the bulk fluid and must be easy to quantify. Miscible compounds, which are transported with the bulk fluid, serve as tracers for the bulk liquid. In aqueous systems, commonly employed miscible tracers include: dyes; metal salts; radiolabled compounds; and hydrogen bubbles. One or more of these compounds will usually do an adequate job of assessing the flow of water and the hydrodynamic transport of dissolved compounds. However, miscible tracers are not suited for determining the transport of particulates in water which are acted on by forces other than the bulk fluid flow (i.e., gravitational forces and straining). Particulate tracers are utilized to study the transport of particles in surface water and ground water applications. Fluorescent plastic beads are a commonly utilized particulate tracer. These particles are easy to quantify and are available in a large range of sizes. However, fluorescent beads are typically too costly to be utilized in field tests where a large initial mass of tracer is required. Furthermore, the surface properties of these beads are often very different than the particles that they are being used to model. Thus, fluorescent beads are not a viable choice for a particulate tracer in most environmental applications. The use of bacteria and viruses as particulate tracers to study the transport of microorganisms in the environment would be highly preferred over fluorescent beads, since they have similar sizes and surface characteristics as the indigenous microorganisms. Furthermore, the large masses of tracer required for field tests are many times less expensive than the fluorescent beads. However, it is often difficult to distinguish the tracer bacteria/virus from the indigenous microorganisms. The U.S. Army developed the use of Bacillus globigii as a tracer for simulating the release of biological warfare agents into the atmosphere. This bacteria is maintained as an inert spore until plated on an appropriate media. When plated, the bacteria grows into a fluorescent orange colony, that is easily distinguished from the indigenous bacteria. Bacillus globigii is a non-pathogenic

bacteria, that is approved for environmental uses. InterBio/Microbe Masters has purchased a license from the Department of Defense (DoD) to use the bacteria as a particulate tracer to quantify the transport of bacteria in paper mill wastewater treatment lagoons. Limited applications of this tracer has hinted at the utility of using B. globigii as a particulate tracer in aqueous systems. However, this particulate tracer has not been utilized in other surface or groundwater applications. Furthermore, the B. globigii tracer has never been compared to existing particulate tracers. The goal of the research was to determine the efficacy of Bacillus globigii as a particulate tracer. By the conclusion of the one-year study period, the usefulness of this bacteria as an environmental particulate tracer was determined. The behavior of Bacillus globigii was compared to currently employed particulate tracers (i.e., fluorescent beads) and common environmental microorganisms. Various flow regimes were used to facilitate this study, including: complete mixed, plug-flow, and porous media.. For each reactor system, a total of 10 replicate tests were conducted using a miscible tracer and the particulate tracer. The mean particle residence time and the coefficient of dispersion were determined for each test. A statistical comparison between the tracers and common microorganisms were conducted to determine if the B. globigii adequately represents the transport of particulates under the particular flow regime. To verify the results of laboratory testing, field tests in a shallow groundwater aquifer and a well mixed lagoon system were conducted and compared to the laboratory results.

Methodology

To attain the objectives delineated above, a research program consisting of three major tasks was conducted. The first task involved the construction of laboratory reactors, including: i) complete mixed, ii) plug-flow, and iii) porous media reactors. In the second task, the transport of Bacillus globigii, fluorescent beads, and common environmental microorganisms was assessed. In the third task, limited field trials were conducted to verify the results of the laboratory investigation. The methodology used in the conduct of the research is outlined below. Task 1. In task one, ideal reactors were constructed for use in the laboratory investigation. Complete mixed reactors (CMRs) were constructed from a 1.8 liter glass tissue culture flasks. The flask contents were mixed using a Teflon coated impellers. The degree of mixing was controlled by the impeller speed and position. Inflow and outflow from the reactor was controlled by a peristaltic pump and a constant 1 liter volume was maintained. Porous media reactors (PMRs) were constructed from glass columns with a 2liter capacity. These reactors were packed with uniform sand (Ottawa Test sand) to simulate an isotropic aquifer. The columnswere operated in an up-flow mode to reduce trapping of air pockets within the sand. Task 2. In task two, the performance of Bacillus globigii as a particulate tracer was assessed. Lithium chloride was used as a miscible tracer to quantify the bulk liquid flow regime. Lithium concentration in the reactor effluent was determined by flame Atomic Absorption Spectrophotometry (AAS). Bacillus globigii concentrations were determined by a pour-plate technique as outlined in Standard Methods (APHA, 1995). To initiate a tracer test, the flow of the reactor was adjusted to a constant rate. This flow rate was maintained throughout the tracer test. Slugs of lithium, fluorescent beads, and B. globigii were added into the reactor inlet zone. The effluent tracer concentrations were measured as a function of time to obtain an exit curve for the reactor. In the clean water tests, small amounts of E. coli were added as a tracer at the same time as the other particulate tracers. This allowed the transport behavior of the surrogate particulate to be determined as a base-line for comparison. Analysis of the tracer performancewas conducted using the traditional exit curve approach. The mean residence time of the water and particulate tracers was determined using the following equation: Equation Where: d/uL = vessel dispersion number (unit-less) The residence time, variance, and vessel dispersion number for the particle tracers were tested for statistical differences. These values were compared to the residence time and vessel dispersion number obtained for the E. coli bacteria in each reactor. Task 3: In task three, the B. globigii tracer was field tested to determine

the feasibility of full scale field application. Testing was performed in a large well mixed wastewater treatment reactors. The data was analyzed as described in Task 2. The results were compared to these obtained in the laboratory reactors. Based on the results of field testing, an economic analysis of the fluorescent bead and B. globigii tracers was conducted to determine if the bacterial tracer is more economical.

Principal Findings and Significance

The B. globigii tracer was compared to a miscible fluorescein dye tracer and E. coli bacteria in Laboratory chemostats. The fluorescein dye washed out of the chemostat much more quickly than the B. globigii tracer or E. coli. Analysis of tracer performance resulted in a residence time (QH) of 63 minutes for the fluorescein, 146 minutes for B. globigii spores, and 138 minutes for E. coli. Statistical analysis of ten replicate tests indicated that the residence time calculated using the miscible fluorescein dye was statistically different than those obtained using B. golbigii or E. coli at a 99% confidence level. However, the residence times obtained using B. globigii and E. coli were not statistically different at the 50% confidence level. Based on these results, it was concluded that the B. globigii tracer would perform much better than typically employed miscible tracers for determining the hydraulic behavior of biological particulates in reactor and surface water systems. The B. globigii tracer was compared to a miscible fluorescein dye tracer and E. coli bacteria in Laboratory columns packed with Ottawa test sand. The breakthrough of the fluorescein dye much more quickly than for the B. globigii tracer or E. coli. Analysis of tracer performance resulted in a break-through time (QH) of 15 minutes for the fluorescein, 75 minutes for B. globigii spores, and 135 minutes for E. coli. Statistical analysis of ten replicate tests indicated that thebreak-through time calculated using the miscible fluorescein dye was statistically different than those obtained using B. golbigii or E. coli at a 99% confidence level. However, the residence times obtained using B. globigii and E. coli were statistically different at the 95% confidence level. Based on these results, it was concluded that the B. globigii tracer would performs differently than typically employed miscible tracers for determining the hydraulic behavior of biological particulates in subsurface systems. However, B. globigii performs differently than E. coli in porous media. It was hypothesized that the difference in behavior may arise from differences between spores and vegetative bacterial cells. The B. globigii tracer was field tested in aerobic and anaerobic digesters. Pre-incubation of samples at 60OC for one hour greatly reduced the growth of bacteria other than B. globigii. This indicates that the tracer can effectively be utilized in biological systems without being over-grown by indigenous bacteria. The tracer curves obtained from field testing were analyzed and the resulting residence times were compared to solids residence times calculated by mass balances on solids in the reactor. In all cases the measured and calculated solids residence times were not statistically different.

Descriptors

Tracer, Particulate, Microorganism, Transport, Hydraulics

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Claghorn, Jennifer. 2000. The Efficacy of Employing Bacillus globigii as a Particle Tracer in Aquatic Systems. M.S. Thesis, Auburn University.

Water Resources Research Institute Reports

Conference Proceedings

Claghorn, Jennifer and Clifford Lange, "The Efficacy of Employing Bacillus globigii as a Particle Tracer in Wastewater Systems" in Proceedings of the 73rd Water Environment Federation Annual Conference and Exposition, Aneheim, CA, October, 2000.

Other Publications

Information Transfer Program

The Institute exists to facilitate interdisciplinary research programs and to encourage communication of the results of research and developments within the water resources field to specialists and to the interested public. The major information transfer activity of the Alabama Institute for the FY-99 program year was co-sponsoring the Annual Alabama Water Resources Conference. This conference provides the opportunity to report experiences, to share progress, and to disseminate research results throughout the water resources community. This conference was co-sponsored with the Alabama Section of the American Water Resources Association, Alabama District Office of the U.S. Geological Survey (Water Resources Division), Alabama Department of Economic and Community Affairs (Office of Water Resources), U.S. Army Corps of Engineers (Mobile District Office), Alabama Power Company, and the Alabama Department of Environmental Management. In addition to the conference, the Institute co-sponsored a symposium with the Alabama Section of the American Water Resources Association. In addition the researchers and their students have published journal articles and made presentations at conferences and symposia. The Institute considers these activities as the very basic form of information transfer. There is also a significant transfer of information by researchers through the courses they teach and the students they advise.

USGS Internship Program