1991-92 Program

Water Resources Research Institute
of The University of North Carolina

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The Institute

The University of North Carolina Water Resources Research Institute was established in 1964 to meet North Carolina's water research needs. A unit of the University of North Carolina system, the Institute is located in Jordan Hall at North Carolina State University. The mission of the Institute is threefold: to identify the state's ever-changing research needs, to motivate and support research by qualified scientists, and to provide for technology transfer. Findings from research funded by the Institute help local, state, and federal agencies make better decisions in managing water resources. To formulate a research program responsive to state water resources problems, the Institute works closely with the North Carolina Department of Environment, Health, and Natural Resources and other agencies. An Advisory Committee representing state and federal agencies, industry, agriculture, the public at large, and local government provides program guidance and review. A Technical Committee of university faculty representing many disciplines also lends professional expertise to Institute programs and activities, particularly in research.

Water Issues in North Carolina

During 1990-1991, events brought into sharp focus the need for better scientific information to support and guide policy decisions and regulatory activities regarding water quality and water resource management in North Carolina.

Deliberations leading to development and adoption in 1990 of North Carolina's Water Supply Watershed Protection Program made evident the need for better technical information for identifying activities that cause the most significant water quality problems in water supply watersheds and the most cost-effective way of controlling pollution from those activities. Attention focused particularly on the need to quantify urban and agricultural nonpoint source pollution and to measure the relative contributions of point and nonpoint sources. There emerged from the watershed protection deliberations a number of technical questions concerning how the regulations will affect water quality, along with the realization that the scientific base for answering many of the questions does not exist.

Water supply development took on a more controversial tone in 1990-91. The state faced renewed debate on interbasin transfer and saw legislation passed establishing a moratorium on such transfers. Court action was initiated in an attempt to prevent one of the exceptions to the moratorium. There was an attempt in the state legislature to preclude the use of a water source located in one political jurisdiction by communities in another. A citizens group brought action to prevent the use of a stream, perceived to be too polluted, for a drinking water supply for a major municipality.

Wastewater disposal continued to be an issue of great concern. Operational problems of large and medium municipal wastewater treatment plants claimed much public attention, but small "package" treatment plants and on-site disposal systems actually contributed more to stream pollution.
The issue of toxic substances in water and sediments of streams and reservoirs grew in importance. Municipalities and industries voiced concern about wastewater regulations regarding toxics that leave them in technical limbo, while public interest groups concerned about possible toxic contamination of drinking water supplies continued to put pressure on dischargers and the regulatory agency.

Because half of North Carolina's population relies on groundwater for drinking water supplies, protection and management of groundwater continued to be a concern. The results of a survey of rural drinking water wells completed in 1989-90 pointed out the need to assess the risk of groundwater contamination by agricultural chemicals.

While population growth in North Carolina is creating the need for additional water supply development and expanded waste disposal facilities, growing environmental awareness among the population is making the development and siting of these facilities more contentious. Scientific information alone will not solve the problems, but without accurate information, there is no technical basis for formulating solutions.

**Priorities**

With these circumstance in mind, the Institute Advisory Committee set priorities for Institute research for the current year. Those priorities are grouped under the three broad categories of water quality, water management, and water quantity.

Within this category, priority topics are the impact of land use on water quality, the relative significance of point and nonpoint sources of pollution, identification and elimination of toxic materials in municipal and industrial wastewaters, development of indices for surface and groundwater quality, examination of transport and fate of nutrients and toxicants in sediments, and evaluation of methods of groundwater restoration.

Among the most important water management research priorities are the effects of interbasin transfer, flood control, drought planning, financing and pricing of water supplies, water conservation, and water reuse.

Although many of the priorities under water management are related to water quantity, there is defined in this category a more narrow set of concerns regarding instream flows. Among these concerns are the dynamics of river and estuarine flows, low flow predictions, and surface and groundwater interaction. Also of concern in this category are groundwater availability and the location, movement, and volume of groundwater.

**Support**

In 1990-91 support for the Institute came from the U.S. Geological Survey through the Water Resources Institute Program (WRIP) and individual matching grants and support from the State of North Carolina through The University of North Carolina system. This was supplemented by the Urban Water Consortium, and contracts with the Division of Land Resources and the Office of Waste Reduction of the N.C. Department of Environment, Health, and Natural Resources; the U.S. Department of Agriculture's Soil Conservation Society and the U.S. Environmental Protection Agency.
1991-92
PROJECTS

Management of Forested Filter Zones for Dispersion and Treatment of Agricultural Runoff (20161)

PRINCIPAL INVESTIGATORS:
E. Carlyle Franklin and James D. Gregory, Department of Forestry, and John E. Parsons, Biological and Agricultural Engineering, North Carolina State University
Starting Date: Aug. 1, 1991
Completion Date: July 31, 1994

This project is being funded by a three-year matching grant to the Water Resources Research Institute from the U.S. Geological Survey.

New Research

It has long been recognized that runoff from agricultural fields contributes significantly to nutrient and sediment loads in streams and lakes. Agricultural best management practices have been developed and implemented in attempts to reduce this contribution. However, the 1989 N.C. Nonpoint Source Assessment showed that approximately 30 percent of all stream miles in North Carolina do not support or only partially support their designated uses and that agricultural pollution is responsible for 67 percent of this nonpoint source degradation. Forested filter zones provide an especially good opportunity to reduce agricultural nonpoint source pollution. Farmers own about 30 percent of nonindustrial private forest lands in the N.C. Piedmont and Coastal Plain, and much of this is riparian forest also bordering agricultural fields. The Conservation Reserve Program is adding to these lands as erodible land is planted with trees. However, on most farms, runoff from fields flows through natural drainage ways in the forested zone so that little filtering of nutrients and sediment takes place. In an earlier study, the investigators demonstrated that it is possible to enhance the filtering effectiveness of forested zones by distributing surface runoff uniformly across the upper portion of the forested zone with a level spreader. In this project, two forested zones equipped with level spreaders will be studied for three years to determine the relationship between filter zone performance and factors such as slope, filter zone distance, microtopography, and vegetation characteristics. The resulting data can be incorporated into recommended best management practices and will be used to develop a model to assist in designing filter zones for water quality protection.

The Role of Biosurfactants in Biodegradation of Hydrophobic Pollutants by Indigenous Microorganisms in Soil (20162)

PRINCIPAL INVESTIGATORS:
Michael D. Aitken and Cass T. Miller, Department of Environmental Sciences and Engineering, University of North Carolina at Chapel Hill
Starting Date: Aug. 1, 1991
Completion Date: July 31, 1994

This project is being funded by a three-year matching grant to the Water Resources Research Institute by the U.S. Geological Survey.

Among the most promising technologies for cleaning up soil contaminated by oil and other hydrophobic pollutants is in-situ biodegradation or degradation by bacteria. However, the potential for biodegradation of contaminants by native organisms in soil may be limited if sorption of contaminants to soil components makes them inaccessible to bacteria. It has been found that some bacteria have the ability to produce extracellular surfactants with the ability to reduce surface and interfacial tension between soil solids and pollutants and thereby enhance the bioavailability of pollutants. The goal of this project is to study biodegradation (by an organism found to produce surfactants) of a hydrophobic pollutant that can be expected to sorb onto soil solids. Polycyclic aromatic hydrocarbons (PAH) will be studied since they are common contaminants. Organisms that can degrade PAH will be isolated from soil contaminated with PAH and screened for surfactant production. Those organisms found to produce extracellular surfactants with the ability to reduce surface and interfacial tension to the greatest extent will be studied further. Effects of biosurfactants on biodegradation will be evaluated, and stimulation of surfactant production and its effects on biodegradation will be studied. The research has direct implications for bioremediation in the field. If the role of surfactants is as significant as expected, the research can lead to an understanding of how to design remediation programs to stimulate surfactant production.
Evaluation of Potential for Aquifer Contamination from Agricultural Chemicals (70114)

PRINCIPAL INVESTIGATORS:
J. Wendell Gilliam and Raymond B. Daniels, Department of Soil Science, and Rodney L. Huffman, Department of Biological and Agricultural Engineering; North Carolina State University
Starting Date: July 1, 1991
Completion Date: June 30, 1992

The Ground Water Education and Testing Program of the N.C. Agricultural Extension Service conducted in 1989-90 found nitrate-nitrogen concentrations exceeding the U.S. EPA health advisory level of 10 milligrams per liter (mg/l) in 5 percent of the private wells tested in N.C. Coastal Plain counties. In many agricultural areas of the United States, nitrate contamination of groundwater has been linked to application of fertilizers, and research in North Carolina has shown high levels of nitrates in very shallow groundwater beneath agricultural fields in the Coastal Plain. However, research in the N.C. Coastal Plain has never found nitrate concentrations greater than 1 mg/l in groundwater below about 25 feet from the surface. Moreover, sampling by the U.S. Geological Survey and the State of North Carolina has shown that major aquifers from which Coastal Plain communities draw drinking water are largely uncontaminated. It is known that in some agricultural areas a clay layer (aquitard) about 25 feet below surface soils prevents movement of nitrates and other chemicals to deeper aquifers, and that in other areas the process of denitrification in the surface soils eliminates nitrates before they can move into deeper groundwater. There are some agricultural areas where neither of these conditions exists, but in these areas, agricultural chemical use is usually low and has been thought to pose no danger. Because no study has concentrated on possible movement of nitrates into deeper groundwater, the discovery of high nitrate concentrations in private wells therefore presents a mystery. It is not known if deeper aquifers are actually being contaminated or if contaminated shallow groundwater is being drawn into poorly constructed wells. The purpose of this project is to determine (1) if there is a danger that nitrates in shallow groundwater under agricultural fields may move into deeper aquifers in the N.C. Coastal Plain and (2) locations where high nitrate concentrations in the surficial aquifer may pose a threat to private drinking water wells. Since there is a definite positive correlation between movement of nitrates and movement of pesticides in groundwater, the project will also indirectly determine the potential for movement of pesticides into deeper aquifers.

Evaluation of Aerobic Pretreatment/Land Disposal Systems for On-Site Wastewater Disposal (70115)

PRINCIPAL INVESTIGATOR:
Aziz Amoozegar, Department of Soil Science, North Carolina State University
Starting Date: July 1, 1991
Completion Date: June 30, 1992

In North Carolina, home building may not take place in areas where soils are unsuitable for septic tank systems unless municipal sewer systems are available. However, high construction and maintenance costs and stringent wastewater discharge regulations prohibit the development of community sewer systems in many areas. As population growth has increased the demand for home building sites, alternative low-pressure pipe septic systems have been approved for use in soils that will not support conventional systems. However, compared to conventional systems, they are quite expensive, and, like conventional systems, they can fail. Many of those installed in the past no longer comply with regulations. Responding to the demand for other on-site disposal options, the N.C. General Assembly has recently approved the use of an on-site household wastewater treatment system that incorporates aerobic pretreatment of waste, disinfection of wastewater, and on-site disposal of wastewater by spray or trickle irrigation. The N.C. Division of Environmental Health is presently working to develop rules for design, installation, and operation of these systems, but there is little information available to assist them in this task. The purpose of this research is to assess the performance of aerobic pretreatment with surface irrigation or subsurface disposal for individual on-site wastewater treatment systems in North Carolina. The study will also address whether the proposed ground absorption loading rates for pretreated effluent could be increased for suitable and provisionally suitable soils. A design manual, based on the research, for individual spray irrigation and trickle irrigation systems will be developed.
Over the next five years, most existing sanitary landfills in North Carolina will close. These landfills were built mainly in the early 1970s and are unlined. Leachate (liquid which results from decomposition of waste in the landfill and which frequently contains toxic contaminants) can be expected to move through soil underlying landfills and into groundwater. Existing regulations require that if groundwater contamination from landfills spreads beyond the landfill boundaries, it must be cleaned up. The most commonly used cleanup technology—pump and treat—is very expensive. Current research suggests that natural biodegradation may reduce or eliminate many hazardous organic contaminants as leachate moves through soil and that there may be ways to enhance this natural biodegradation to help contain contaminants within landfill boundaries. This project will build on research completed by Robert C. Borden and J. L. Douglas which indicated that contaminants in leachate from a Raleigh landfill are being biodegraded as the liquid moves through soil. This project will confirm that apparent biodegradation of contaminants and will measure the rate of degradation of certain contaminants under both field and laboratory conditions. Knowing the rate of biodegradation will make it possible to project the distance between the edge of a landfill and a regional aquifer or stream required to fully degrade a contaminant. This knowledge will assist state regulators in the development of priorities and strategies for the management of landfills in North Carolina which are releasing leachate to groundwater.

Chlorination of raw water containing high concentrations of natural organic matter and color often produces high concentrations of trihalomethanes (THMs), which are suspected carcinogens regulated by the EPA. Although small water systems are not yet required to monitor routinely for THMs, there is a great deal of concern about possible high levels of these substances in the drinking water of small towns, particularly in parts of the Southeast. The state regulatory agency recently enforced a temporary ban on drinking water produced by the Washington, N.C., water system because THMs were 13 times the federal limit. Most of the alternatives to chlorination for treating drinking water are very expensive and may have other disadvantages, leaving small systems facing the possibility of greatly increased treatment costs to comply with expected regulations. Small systems need a cost-effective method to further treat chlorinated water to remove precursors to chlorination by-products. Treatment by membrane systems may be attractive for small utilities since operating costs for such processes can be competitive. However, membrane separation systems can accumulate organic matter and become fouled. In this project, the investigator will examine a treatment system that combines powdered activated carbon (PAC) with membrane separation. The hypothesis is that membrane fouling can be reduced by the scouring effect of recirculating PAC particles as a slurry flowing across the membrane surface. The purpose is to demonstrate that a PAC-membrane treatment system can be cost-effective for small water systems and can produce drinking water of outstanding quality.
Disinfection By-products in North Carolina Drinking Water (50168)

PRINCIPAL INVESTIGATOR:
Philip C. Singer, Department of Environmental Sciences and Engineering, University of North Carolina at Chapel Hill
Starting Date: Jan 1, 1991
Completion Date: April 30, 1992

This project is funded by the N.C. Urban Water Consortium

Trihalomethanes, suspected carcinogens created as by-products of chlorine disinfection of raw water containing humic substances, are regulated in drinking water by EPA, and it is expected that the current maximum contaminant level (MCL) for total THMs will soon be revised from 10 micrograms per liter (µg/l) to 50 or 25 µg/l. It has been shown that because waters in North Carolina have high concentrations of organic carbon (TOC), high concentrations of trihalomethanes (THMs) result from chlorination. An examination in 1988 of compliance records maintained by the N.C. Public Water Supply Branch revealed that the mean THM concentration in water from the 61 N.C. utilities that serve more than 10,000 customers was about 64 µg/l and that 38 of the systems had THM levels above 50 µg/l. Research has shown that a variety of other disinfection by-products (DBPs) are formed during drinking water treatment, and a number of these are also being considered for regulation by EPA. This project is aimed at ascertaining the extent of DBP formation in finished drinking waters of the members of the N.C. Urban Water Consortium so that these utilities can be in a position to take remedial action to control formation when MCLs are revised and/or established. Samples of raw water, water at the point of chlorine application, water at two other points in the treatment system, and finished drinking water entering the distribution systems will be collected from the Raleigh, Durham, Winston-Salem, High Point, Burlington, and OWASA waterworks and will be analyzed for TOC and for DBPs. In addition, regression analysis will be performed on the data to test for correlations among the specific DBPs identified, among classes of DBPs, between specific DBPs and total organic halide (TOX), between DBP formation and TOC concentration at the point of chlorine addition, and between DBP formation and chlorine utilization (chlorine applied minus residual chlorine). Finally, the results will be used to assess the effectiveness of adding chloramines to treated water at the entrance to the distribution system to inhibit DBP production in the distribution system, and recommendations will be made for DBP control.

An Evaluation of Enhanced Aquifer Remediation Strategies for Subsurface Restoration (70117)

PRINCIPAL INVESTIGATOR:
Cass T. Miller, Department of Environmental Sciences and Engineering, University of North Carolina at Chapel Hill
Starting Date: July 1, 1991
Completion Date: June 30, 1992

A 1989 survey in North Carolina reported that 600 underground storage tanks containing substances such as petroleum products and chlorinated solvents were leaking and actually contaminating or threatening to contaminate groundwater. In addition, thousands of steel underground storage tanks containing such substances are approaching or exceeding their design life of 20 years and can be expected to leak. The most common method of cleaning up groundwater contamination from sources such as underground storage tanks is to pump groundwater out of the aquifer, treat it, and return it to the aquifer. A 1990 national survey concluded that this method has not been documented as successful in reaching existing mandated clean-up levels at even one site in the United States. Some researchers insist that this method will never be effective. This project is aimed at evaluating other aquifer remediation strategies, specifically (1) organic solvent extraction, (2) thermal extraction, (3) vapor-phase extraction, and (4) hydraulic containment. In addition to evaluating each remediation strategy, the investigator will develop a two-dimensional multiphase flow and transport model capable of evaluating experimental data collected and predicting the response of porous media systems to combinations of single processes. The results from experiments and model analysis will be used in an economic analysis to determine the lowest contaminant levels achievable at a given cost and the cost and time required to achieve a typical cleanup standard.
This project is a continuation of a project with the same title (70109) which ends September 30, 1991. The purpose of the project is to enhance the ability of reservoir managers and water quality regulatory agencies to predict water quality in Piedmont freshwater reservoirs by (1) identifying and modeling biological responses to gradients of sediment and phosphorus loading and (2) characterizing nutrient and sediment loadings to Piedmont urban and agricultural reservoirs. During the first part of the study, the investigators experimentally determined the response of aquatic communities to gradients of suspended sediment and high phosphate enrichment in an urban reservoir and used the data to develop a model for predicting water quality in Piedmont urban reservoirs. In this phase of the project, they will cross gradients in both phosphorus enrichment and suspended sediment loading, using multiple combinations of both, to determine the threshold conditions that promote blooms of noxious algae. They will also monitor nutrient and suspended sediment loading and water quality during precipitation events in representative urban and agricultural reservoirs. Finally, they will use data gathered through experiments and monitoring to complete the predictive model, modifying it for application to both urban and agricultural Piedmont reservoirs.

Conservation tillage (one form of which is no-till) has been hailed as a method of protecting water quality by reducing erosion from agricultural fields and therefore sedimentation in nearby streams. No-till, which leaves crop residues covering the soil surface, has also been promoted as a way of conserving soil moisture and increasing water available to plants by retarding evaporation. However, there are concerns that conservation tillage may require farmers to use more herbicides to control weeds in crops, and there is evidence that soluble nutrient concentrations in runoff increase with increased residue cover. Moreover, there is also evidence that conservation tillage may have detrimental effects on soil physical properties. Using data from long-term till and no-till studies at Agricultural Research Service stations in Reidsville and Rocky Mount and newly established experimental till and no-till plots at stations at Reidsville and Kinston, the investigators on this project will quantify pesticide and nitrate leaching under different tillage system/soil type combinations. In addition, rainfall simulation studies will provide information regarding the potential for chemical transport of some commonly used pesticides under a wide range of soil environmental conditions. It is their intention to identify specific agrichemical problems that arise from soil management methods and to improve the ability to predict which management methods are most effective with various N.C. soils for enhancing water quality.
The City of Durham is facing the possible expenditure of nearly $100 million for expansions to its water and wastewater treatment plants within the next 5 years. Another round of similar expansions will be necessary within the next 10 to 15 years if present growth projections are realized. Investments of this magnitude for a utility that serves about 150,000 people has raised several questions: Can water conservation improve the efficiency of those investments? If so, by how much? How would conservation affect revenues and expenditures, and how might it affect rates charged to customers? In addition, expansions of the city's wastewater treatment plants in the next 5 years will nearly exhaust the assimilative capacities of receiving streams. What will happen when the city seeks discharge permits for additional expansions? By how much can water conservation reduce the volume of wastewater that must be treated and discharged. The purpose of this study was to provide responses to these questions. The study includes an analysis of water use characteristics and wastewater flows in Durham, estimates of the economic efficiency gains possible from water conservation, and benefit-cost analyses of general types of conservation and of a specific program for water conservation in residential bathrooms. The study also explores revenue implications of conservation. It concludes that although conservation cannot mitigate the need for immediate expansion of Durham's water and wastewater facilities, an aggressive conservation program could be expected to extend the useful lives of facilities to be built in the 1990s and thereby delay additional expansions now planned for the following decade.

Continuing Research

Although it is widely recognized that population growth and development are increasing nutrient and sediment loadings to water supply reservoirs in Piedmont North Carolina, the ability to predict the effects of increased loadings on water quality and biological resources remains limited. In this project, investigators will develop an innovative multidisciplinary approach to predicting water and biological resource quality of Piedmont reservoirs undergoing urban development. A limnologist/algal ecologist will join forces with an environmental engineer to examine the response of aquatic communities to imposed gradients of sediment and phosphorus loading. Field and laboratory experiments will be employed in this phase of the research. In another phase, the investigators will inventory and evaluate models currently used to predict reservoir water quality and will select the model most suitable for use in Piedmont reservoirs. Experimental data will be used to test improved mathematical formulations that describe the dynamics of water and biological quality in reservoirs and to provide a base for selecting and modifying chemical and biological parameters for the process-based model. The project will strengthen the ability of reservoir managers and regulatory agencies to predict impacts of variable sediment and nutrient loadings on reservoir systems.
Evaluation of Long-Term Institutional and Financial Approaches for Maintaining Stormwater Management Systems (70111)

PRINCIPAL INVESTIGATORS:
Raymond J. Burby and Edward J. Kaiser,
Department of City and Regional Planning,
University of North Carolina at Chapel Hill
Starting Date: Oct. 1, 1990
Completion Date: Sept. 30, 1991

While many of the engineering and design problems related to urban stormwater management are adequately understood, a number of questions concerning implementation and the long-term functional integrity of stormwater management systems need to be addressed. Answering these questions is of critical importance since the U.S. EPA has promulgated urban stormwater management regulations in 1990 and because the Federal Emergency Management Agency is encouraging community stormwater management as part of the National Flood Insurance Program. In this project, investigators will survey local governments and consultants in North Carolina and will conduct technical literature analyses to answer the following questions: (1) How does stormwater facility design relate to the cost and ease of long-term maintenance? (2) What are the most frequent and important causes of stormwater facilities failure and what can be done to mitigate those causes? (3) Have effective policies been developed to deal with disposal of material dredged from detention and retention ponds? (4) How often must maintenance procedures be performed and what is the cost of maintenance for various stormwater facilities? (5) What are the advantages and disadvantages of “preventive” versus “as-needed” approaches to stormwater management system maintenance? (6) What is the appropriate division of responsibility between the public and private sectors for maintenance of components of an urban stormwater management system? (7) What are the most cost-effective methods of providing stable, long-term financing of the maintenance of stormwater management systems?

An Evaluation of An Approach for Determining the Cause of Chronic Toxicity in the Effluent from Municipal Wastewater Treatment Plants (70103)

PRINCIPAL INVESTIGATORS:
Donald E. Francisco, and Francis A. DiGiano, Department of Environmental Sciences and Engineering, University of North Carolina at Chapel Hill
Starting Date: July 1, 1989
Completion Date: Aug. 31, 1991

This project is being funded by the N.C. Urban Water Consortium.

Many wastewater treatment plants in North Carolina are currently required to meet chronic toxicity limits as a condition of the National Pollutant Discharge Elimination System (NPDES) Permit. Many of these plants are having difficulty meeting this permit limit. Unlike acute toxicity, there currently are no accepted methods to trace the source of chronic toxicity so that this might be eliminated either at the source or by treatment. This research will test a relatively simple technique which wastewater treatment plant personnel may utilize for identifying the source of chronic toxicity. The research proposes to test the precision of the chronic toxicity test and other factors which might contribute to chronic toxicity in effluents which are tested at very high effluent concentrations and have no obvious source of toxic influent. The results of this research will identify whether a relatively straight-forward but labor intensive, evaluation system has utility for identifying the source of chronic toxicity. The results of this research will be beneficial in evaluating the nature of the Ceriodaphnia chronic toxicity bioassay test in systems which have a very high regulatory, in-stream waste concentration. Such information may lead to modifications of the bioassay testing procedure.
Determining the Role of Nitrogen-Enriched Acid Rain in Estuarine Eutrophication: The Neuse River Estuary, NC (20157)

PRINCIPAL INVESTIGATOR: Hans W. Paerl, Institute of Marine Sciences, University of North Carolina at Chapel Hill
Starting Date: July 15, 1990
Completion Date: July 14, 1993

This project is being funded by a three-year matching grant to the Water Resources Research Institute by the U.S. Geological Survey.

Acid rain and associated dry deposition constitute a significant, yet frequently overlooked and unassessed source of biologically available nitrogen in shallow East Coast estuaries. According to some preliminary estimates, atmospheric nitrogen inputs to major East Coast estuaries may contribute from 20 to 40 percent of the total nitrogen loading. The increasing frequency of nuisance algae blooms and the resulting water quality degradation in these waters suggest that the role of atmospheric nitrogen loading in estuarine eutrophication should be quantified. This research will examine productive and trophic impacts of atmospheric nitrogen deposition on the Neuse River Estuary. The research team will measure nutrients and physical and biotic features of the river area being studied bimonthly. They will analyze wet and dry deposition inputs, evaluate other point and nonpoint nutrient input sources, and assess the relative importance of atmospheric deposition through short-term in situ bioassay and longer-term mesocosm studies. The studies will help determine which constituents of acid rain stimulate or inhibit phytoplankton growth; if acid rain events can be linked spatially and temporally to phytoplankton production or community composition; if acid rain plays a specific role in estuarine eutrophication and nuisance bloom dynamics; and how acid rain affects the trophic transfer between phytoplankton and zooplankton.

Effectiveness of Vegetative Filter Strips in Removing Sediments, Nitrogen, and Phosphorus from Agricultural Drainage (70105)

PRINCIPAL INVESTIGATORS: J. W. Gilliam and R. B. Daniels, Department of Soil Science, North Carolina State University
Starting Date: July 1, 1989
Completion Date: June 30, 1992

This project is being jointly funded by the U.S. Environmental Protection Agency, the USDA Soil Conservation Service, and WRRI.

Vegetative filter strips (VFS) between agricultural fields and surface waters have long been promoted by the U.S. Department of Agriculture and the U.S. Environmental Protection Agency as techniques to remove sediment from surface drainage water before it enters perennial streams or other surface waters. This project is aimed at providing data for answering questions about the effectiveness of VFS for water quality purposes. The project consists of experimental studies and a modeling effort to allow extension of the data collected to different climatic, soil and geomorphic conditions. The results will be useful both technically, in establishing design criteria for filter strips, and in the policy area by providing analysis criteria for stream buffer requirements and other regulations.

A Study of Baseline Water Quality in Lake Raleigh (50165)

PRINCIPAL INVESTIGATOR: JoAnn M. Burkholder, Department of Botany, North Carolina State University
Starting Date: July 1, 1990
Completion Date: Sept. 30, 1991

This study is being funded by the NCSU Centennial Campus

Lake Raleigh is a small urban reservoir located on NCSU’s Centennial Campus. It is anticipated that the chemistry and morphometry of the lake may be modified by construction activities in its drainage basin. It is, therefore, desirable to document present conditions as a reference point for comparison with future changes in reservoir water quality. In this project, a bathymetry map will be developed for the lake, and three stations for monthly sampling will be established to include the near-inflow area, midregion, and near-outflow of the lake. Water clarity will be assessed. Light, temperature, turbidity, dissolved oxygen, pH, conductivity, and suspended solids will be determined. A nutrient analysis will be performed, as will monthly analyses for fecal coliform bacteria and quarterly analyses for heavy metals. Biological parameters other than fecal coliforms in the baseline assessment of water quality in Lake Raleigh will include monthly chlorophyll samples and late-summer assessment of the taxonomic composition and abundance of the phytoplankton community.
Economic Impacts of Pesticide Regulations to Protect Groundwater (20159)

PRINCIPAL INVESTIGATORS:
Leon E. Danielson and Gerald A. Carlson, Department of Economics and Business, and Jerome B. Weber, Department of Crop Science, North Carolina State University
Starting Date: July 15, 1990
Completion Date: July 14, 1992

This project is being funded by a two-year matching grant to the Water Resources Research Institute by the U.S. Geological Survey.

In December 1988, the Environmental Protection Agency reported detections of 74 pesticides in the groundwater of 38 states, raising the possibility of widespread, serious pesticide contamination of groundwater supplies. Assessments of the potential for pesticide contamination of groundwater have, however, been controversial. Such assessments have been done without relevant local or regional input and without consideration of several critical hydrogeologic factors, including the characteristics of pesticides and site-specific soil characteristics. Moreover, local officials responsible for selecting policies to protect groundwater from pesticide contamination rarely have information about how well various policies protect groundwater or how the policies affect consumers and agricultural producers economically. This research will provide missing information that policy makers need to assess the pesticide contamination threat and select the most efficient policies to protect groundwater resources. An improved, more comprehensive pesticide use database will be developed, and missing hydrogeologic facts will be incorporated into a model to estimate contamination potential for selected pesticides in areas of the Southeast Coastal Plain. Once the contamination potential information is available, estimation of the economic impacts of alternative policies designed to reduce the contamination potential will be analyzed using producer and consumer economic impact models.

Biomarkers for Redox-Active Genotoxins in Contaminated Sediments: A Mechanistic Approach (20158)

PRINCIPAL INVESTIGATOR:
Richard T. Di Giulio
School of Forestry and Environmental Studies, Duke University
Starting Date: July 15, 1990
Completion Date: July 14, 1992

This project is being funded by a two-year matching grant to the Water Resources Research Institute by the U.S. Geological Survey.

It has been shown that persistent contaminants in rivers, lakes, and estuaries frequently collect in bottom soils or sediments, and recent studies have revealed elevated rates of tumors in bottom-dwelling fish taken from contaminated environments. These observations have generated considerable concern about the direct impacts of contaminants on aquatic ecosystems and indirect impacts of contaminants on human users of contaminated systems. There is, therefore, an important need for methods for assessing the hazards posed by contaminated sediments to aquatic systems and people who use them. This project focuses on genotoxins that have been associated with tumors in fish and on the role played by free radicals in genotoxic sequelae and their implications for biomonitoring. The goal is to develop a sensitive, mechanistically based approach for monitoring DNA damage and associated indices of oxidative stress and contaminant metabolism in benthic fish exposed to contaminated sediments. Laboratory in vivo studies will employ intact sediments from two streams in the Niagara River system. These experiments will serve to quantify relationships between exposures to sediments and responses indicative of genotoxicity, oxidative stress, and hydrocarbon metabolism. Initial in vitro studies will serve to assess the abilities of representative model compounds to redox cycle and generate free radicals and to select one compound for detailed investigation of free radical-mediated mechanisms of DNA change. In the second year of the project, field studies employing both wild and caged fish will be conducted in Niagara River system streams that will closely parallel the in vivo laboratory studies. Collectively, these integrated laboratory and field studies will provide for creation of a sensitive and practical methodology for assessing the bioavailability and genotoxic impacts of compounds widely occurring in sediments of contaminated aquatic ecosystems. The methodology will have very practical uses for evaluating contaminated systems, prioritizing areas for clean-up efforts, and determining the success of clean-up efforts.
The suitability of Jordan Lake water for public consumption has been extensively debated. Questions of synthetic organic chemicals (SOCs) which may be carcinogenic to man, disinfection by-products, and disinfection efficiency are of interest to local water supply practitioners. The goal of this project is to evaluate the potential health hazards arising from the use of Jordan Lake as a source of drinking water. This project will explore three different potable water treatment scenarios for Jordan Lake water. A conventional surface water treatment scheme using coagulation, sedimentation, filtration, and chlorination will be compared with two advanced treatment schemes, one using granular activated carbon adsorption, the other using ozonation and chloramination in place of chlorine for disinfection. Treatment effectiveness will be evaluated using conventional water quality characteristics (e.g. turbidity, color, total organic carbon, trihalomethanes) and the Ames mutagenicity bioassay.

The major limitation in predicting groundwater contamination is the lack of understanding of the interactions among the processes involved in the dissipation of organic solutes in soil under natural conditions. Pesticides are an important source of such potential contaminants. Pesticide behavior in soil is effected typically by the processes of advection, hydrodynamic dispersion, evapotranspiration, volatilization, sorption/desorption, and degradation. While much work has been done in the area of pesticide process reactions, few studies have examined all of the operative processes for a given system. This project will add new information about the interaction of processes that affect the fate and transport of common organic solutes in the unsaturated soil zone. The expected results will also include new information about the feasibility of using polymers to limit the mobility of potential groundwater contaminants. The research includes controlled field studies, laboratory process studies, and mathematical modeling of field and laboratory studies.
Effects of Drainage and Water Table Control on Groundwater and Surface Water Quality (50160)

PRINCIPAL INVESTIGATORS:
R. Wayne Skaggs, Robert O. Evans, and John E. Parsons, Department of Biological and Agricultural Engineering; J. Wendell Gilliam, Department of Soil Science; and T. Jackson Sheets, Departments of Entomology, Crop Science, and Horticultural Science; North Carolina State University
Starting Date: Aug 1, 1990
Completion Date: July 31, 1991

This project is being funded by a three-year matching grant to the Water Resources Research Institute by the U.S. Geological Survey.

A Study of Nitrate Movement to Ground Water at the Neuse River Wastewater Treatment Plant Facility (50167)

PRINCIPAL INVESTIGATOR:
Charles W. Welby, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University
Starting Date: Aug 1, 1990
Completion Date: Aug 31, 1993

This study is being funded by the City of Raleigh through the N. C. Urban Water Consortium.

Poorest drained agricultural soils account for 40 percent of North Carolina's total cropland. Nationwide, 25 percent of agricultural cropland is composed of poorly drained soils. Because poorly drained areas lie near creeks, rivers, and estuaries, nonpoint source pollution from such areas used for agriculture pose a significant potential threat to surface waters. Moreover, agricultural nonpoint source pollution may also threaten groundwater. Research has shown that drainage and water table control practices can affect the rate and pathway of water draining from agricultural lands. This knowledge has led to development of controlled drainage methods which are now being used as best management practices (BMPs) on thousands of acres in North Carolina and other Atlantic coast states. However, present methods for predicting effects of water management and cultural practices on pollutant loading are limited. Current methods cannot predict the effects of changing fertilizer rates or the time of fertilizer application or determine the best way to manage controlled drainage systems to minimize pollutant loading. Little research has been done on the effects of water table management on pesticide movement and fate in the groundwater and surface water of poorly drained soils. This study will determine the effects of drainage and related water table control practices on groundwater and surface water quality, with particular focus on the movement and fate of pesticides and nutrients. Data on water quality effects of BMPs will be collected through well-instrumented, precisely controlled field experiments. The data will then be used to test the reliability of simulation models for predicting the fate of pollutants in surface and groundwaters. The most promising of these models will be further developed to improve their reliability for shallow water table conditions. The results will be useful to state and federal agencies, consultants, and farmers who are developing, evaluating, and applying methods for reducing nonpoint source pollution.

A previous study at Neuse River Wastewater Treatment Plant sludge application site has shown nitrate contamination of groundwater at some fields, suggesting the need for more detailed studies to determine possible various routes of nitrate movement into groundwater and to surface water. This research will utilize three test sites at the Neuse River Wastewater Treatment Plant facility. At Site 1, a field which borders a stream and which has not yet been used for sludge application, background information about groundwater and surface water quality will be gathered first. Then, as sludge is applied, the effects on the groundwater and surface water system will be studied. At Site 2, a field where sludge has been applied for several years, sampling of a number of monitoring wells will be conducted weekly for specific conductance, pH, and water level; monthly for chloride, nitrate, sodium, potassium and calcium; and quarterly for more complete analyses. These data will provide insight into the actual movement of nitrate through the vadose zone into the saturated zone and then toward stream discharge areas as well as an understanding of the potential for contamination of a bedrock well by nitrate originating in sludge. At Site 3, located on NCSU's Randleigh Dairy Farm, four wells will provide information on nitrate movement to the shallow groundwater for three different potential sources of nitrate: commercial fertilizer applications to a grain field, dairy barns and feed-
A Mound/Constructed Wetland System for On-Site Wastewater Treatment (70101)

PRINCIPAL INVESTIGATOR:
Stephen W. Broome, Department of Soil Science, North Carolina State University
Starting Date: July 1, 1989
Completion Date: Dec. 31, 1991

Over 50 percent of North Carolinians rely on septic tank systems for managing their household wastewater. The soils in the N.C. Piedmont and Mountain regions (occupying 55 percent of the state) are characterized by the presence of saprolite at or near the surface. Present N.C. rules governing septic tank systems consider saprolite as unsuitable for wastewater disposal; however, changes are underway to reclassify some saprolite for direct wastewater application. Because of the presence of cracks, foliations, natural dikes, and various pores in saprolite it is suspected that direct application of wastewater to saprolite will result in the rapid movement of pollutants into the groundwater. In light of the lack of information it is difficult to determine if any saprolite is suitable for wastewater disposal. Also, the procedures by which suitable material could be recognized are not clearly established. This research is aimed at identifying properties of various saprolites associated with the major soils and rock types in the two regions, and developing procedures to identify suitable saprolites for septic tank systems. The information obtained in this study will help the regulatory agencies to develop rules and regulations regarding use of saprolite for wastewater disposal in Piedmont and Mountain regions. This information will also be important for assessing groundwater recharge and movement of other inorganic chemicals in waste materials such as sludge or landfill leachate throughout the soils of the two regions.

Evaluation of Saprolite in the Piedmont and Mountain Regions for On-Site Wastewater Disposal (20154)

PRINCIPAL INVESTIGATORS:
Aziz Amoozegar, M.T. Hoover and H. J. Kleiss, Department of Soil Science, North Carolina State University
Starting Date: Sept 1, 1988
Completion Date: June 30, 1992

This project is being funded by a three-year matching grant to the Water Resources Research Institute by the U.S. Geological Survey.

As development continues in the coastal zone of North Carolina, the need for effective treatment of wastewater becomes more critical. Incomplete treatment of wastewater leads to pollution of groundwater, streams and estuaries. Because of the high cost of municipal wastewater treatment plants and the rural nature of most of the area, on-site treatment is usually the only alternative. This poses a dilemma since much of the land within the coastal zone is unsuitable for effective wastewater treatment using conventional septic tanks and associated absorption fields. Soil limitations are perched or seasonal high water tables, slowly permeable clays or coarse textured sands which offer very little treatment potential. An alternative treatment system, the pressure dosed septic system, has been successfully used to overcome some soil problems; however, this system does not effectively treat wastewater during periods of seasonal high water tables or when installed in massive clays. This research will determine the ability of a combination mound and constructed wetland system to improve the quality of wastewater passed through it via subsurface flow from a septic tank serving a single family dwelling. Constructed wetlands may be used to upgrade existing systems or to build new systems. The principal benefit of the results will be to develop an improved method of wastewater treatment that will reduce the risk of pollution by nutrients, suspended solids and disease organisms.
N.C. Urban Water Consortium

In 1985, the Institute in cooperation with several of North Carolina's larger cities, established the North Carolina Urban Water Consortium. The Consortium is designed to provide a program of research, development and technology transfer on the many water problems that urban areas share. The Consortium program is administered by the Institute. Participating cities support and guide the program through annual dues, which are matched by state funds, and representation on an advisory board. Membership in the Consortium is open to all cities and special districts in North Carolina. In 1990-91, the cities of Charlotte and Greenville joined the Consortium, bringing the number of members to eight.

Information Dissemination and Technology Transfer

The Institute disseminates information and promotes the adoption of new technology through publication of newsletters and of technical completion reports on its projects and through conferences, workshops, and seminars.

Eight completion reports and a special historical report were published in 1990-91. Each report received peer review as required by Institute publication policy, and the availability of the reports was publicized by review in the Institute newsletter and by special mailings to members of the research and regulatory communities. Reports published were:

- Report 253 Stable Isotope Tracers of Nitrogen Sources to the Neuse River, North Carolina
- Report 254 Analysis of Stormwater Infiltration Ponds on the North Carolina Outer Banks
- Report 255 Characterization of Soils and Saprrolites from the Piedmont Region for Waste Disposal Purposes
- Report 256 Impact of Safe Drinking Water Act Amendments of 1986 on Selected Utilities in North Carolina
- Report 257 Precipitation Regime Changes Associated with Climatic Changes
- Report 258 Quest for Clean Streams in North Carolina: An Historical Account of Stream Pollution Control in North Carolina
- Report 259 Identification of Mutagenic By-Products from Aquatic Humic Chlorination
- SRS No. 6 Investigation of Odor Problems Associated with Wastewater Treatment Facilities in North Carolina
- SRS No. 7 Water Conservation in Durham: Economic and Financial Impacts of Selected Programs

If you would like a complete listing of reports and proceedings published by the Institute, please call (919) 515-2815 and request the Institute Publications List.
Newsletters

The Institute NEWS, a 14-page newsletter, was distributed bimonthly to about 2,900 federal and state agencies, university personnel, multi-county planning regions, city and local officials, public interest groups, consultants, and private citizens. The NEWS regularly includes articles on water-related topics ranging from current federal and state legislation and regulatory activities to new research findings and listings of water-related publications. The Urban Water Consortium News is published periodically and distributed to members of the Urban Water Consortium who use the newsletter to keep their constituencies (city councils, county commissions, etc.) informed about the activities of the Consortium and about water-related issues affecting municipalities. The newsletter carries descriptions of research funded through the Consortium as well as news about water-related projects undertaken independently by members, and state and federal programs and legislation.

Other Publications

Institute staff also participated in the development and editing of several non-Institute publications. In connection with a statewide conference sponsored by the N.C. Office of Waste Reduction/Pollution Prevention Program, the associate director and technology transfer specialist compiled and edited A Handbook for Using a Waste-Reduction Approach to Meet Aquatic Toxicity Limits. Under an arrangement through the Urban Water Consortium, the technology transfer specialist compiled and edited a handbook on xeriscape (water-conserving landscaping) for the City of Raleigh.

Conferences, Workshops, and Seminars

During 1990-91 the Institute sponsored and helped plan and execute a major conference, a series of workshops, and a seminar on key water-related issues. Following is a brief description of them.

Analysis of Stormwater Infiltration Ponds Seminars. In September, WRRI had a funded researcher present his findings in a morning presentation and an afternoon application session. Federal, state, and local officials were invited to participate in the day-long event. Thirty-one people attended.

Erosion and Sediment Control Workshops. During February and March 1991, WRRI, the N.C. Sedimentation Control Commission, and the Land Quality Section of the N.C. Department of Environment, Health, and Natural Resources presented ten workshops in various locations across North Carolina to acquaint contractors with new state erosion and sediment control rules. A total of 388 people attended.

Waste Reduction Approach to Meeting Toxicity Limits. In May, WRRI joined the N.C. Office of Waste Reduction/Pollution Prevention Program in organizing and presenting a major statewide conference aimed at assisting industries and wastewater treatment plants in incorporating waste-reduction principles into processes and practices to eliminate or reduce effluent toxicity problems. The conference was cosponsored by the N.C. Textile Manufacturers Association, Professional Engineers of North Carolina, Citizens for Business and Industry, American Association of Textile Chemists and Colorists, and Radian Corporation. One hundred twenty-eight people attended.
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