FISCAL YEAR 1988 PROGRAM REPORT

WATER RESOURCES RESEARCH INSTITUTE
THE UNIVERSITY OF RHODE ISLAND
RHODE ISLAND
FISCAL YEAR 1988 PROGRAM REPORT

Water Resources Research Institute
University of Rhode Island
Rhode Island
ABSTRACT

The 1988 program objective was to conduct studies and research of value to the New England region as well as to assist in the solution of water resources problems in the State of Rhode Island. Current and anticipated state and regional water problems are contamination of groundwater by natural radioactivity from radon or chemicals from industrial and agricultural activities, slow progress in pretreatment programs leading to continuous surface water contamination, delayed cleanup actions of landfills with hazardous wastes resulting in pollution of aquifers, and lack of public awareness as well as participation in water quality protection and management. The FY-1988 program addressed many of these problems. Uranium, U, and Thorium, Th, which decay to radon were found to be higher in alkaline rocks. The plutonic rocks range from 2.2 to 22.8 ppm with the highest U consistently found in the peralkaline Rhode Island Quincy Granite and on-feldspar hypersolous Scluate Granite. Contaminants from aquifers can be cleansed by natural flushing. By modeling the occurrence of rainstorms by a Poison process, and using a two-dimensional Galerkin finite-element procedure, the time required for restoring the water quality can be predicted. Leachates from an incinerator ash landfill did not contain cadmium and lead at hazardous levels. A HELP computer model was useful to simulate a landfill, predicting leachate generating rates. Nutrient retention in vegetative buffer strips were found to be related to nitrate uptake rate and the rate of nitrate reduction in plant roots. Microbial denitrification rate affects the rate of retention, depending on the pH and organic content. Heavy metals, Pb, Cd, Ni and Zn could be removed by Arthrobacter SL-1 in Pipes buffer at pH 5.5 from 94 to 98%. A plasmid has been isolated and successfully cloned to E. Coli HB101 with strong resistance to Cd toxicity. Electroflotation process was found to be successful in removing heavy metals and cyanides simultaneously. Information transfer included watershed watch, groundwater protection conference plus short courses and distribution of fact sheets and a newsletter. This Center works closely with the R. I. Dept. of Environmental Management; USGS Subdistrict Office, R. I. Solid Waste Management Corp., and other New England Water Resources Centers for program planning and research coordination.
| ABSTRACT | .......................................................... | 1 |
| WATER PROBLEMS & ISSUES OF RHODE ISLAND | .................................................. | 1 |
| PROGRAM GOALS & PRIORITIES | .................................................. | 3 |
| RESEARCH PROJECT SYNOPSIS | .................................................. | 7 |
| 02 Uranium-Thorium Concentrations in Bedrock and Surficial Materials: Primary Sources of Radon in Rhode Island Aquifers - O. Don Hermes | 7 |
| 03 Stochastic Study of the Natural Flushing of Contaminants from Aquifers - S.L. James Hu | 19 |
| 05 Evaluating Plants for Nutrient Retention in Vegetative Buffer Strips - R.J. Hull | 32 |
| 06 Microbial Processes Controlling the Fate of Nitrogen in Vegetative Buffer Strips - P.M. Groffman | 38 |
| S1 Study of Fly Ash & Bottom Ash & Their Leachate Characteristics in a Simulated Landfill Condition - C.P.C. Poon | 45 |
| S2 Simultaneous Removal of Cyanide & Heavy Metals from Industrial Process Wastewaters - C.P.C. Poon | 47 |
| INFORMATION TRANSFER ACTIVITIES | .................................................. | 49 |
| COOPERATIVE ARRANGEMENTS | .................................................. | 52 |
| TRAINING ACCOMPLISHMENTS | .................................................. | 54 |
In recent years, Rhode Island and the other New England States have experienced a very high rate of growth. The rapid housing and commercial development in Rhode Island presents a potential threat to surface and groundwater contamination, threatening the water quality in the state. Sediments, nutrients, and toxic chemicals in watersheds with high development activities could be washed into streams, lakes, and ponds, or infiltrate into aquifers. While most municipal wastewater treatment facilities are being upgraded and pretreatment programs are being implemented in most towns and cities, the water quality in our surface water in the state still needs improvement.

Known petrologic and geochemical characteristics of geologic materials in Rhode Island suggest anomalously high concentrations of radioactive parent nuclide of radon and radium. Radon is an inert gas which is relatively soluble in water. These properties allow it to readily diffuse into the atmosphere including the confined household space or into groundwater aquifers. Presently, all new houses built in Rhode Island are tested for radon. Characterization of radon in groundwater and radioactive parents in host aquifers will permit the state to focus on specific geographic areas where health hazards are likely to exist.

In Rhode Island, more than a dozen contaminations of aquifers due to spills and leaks of organic materials have been reported in the past few years. Restoration of aquifer water quality is expensive. One alternative is to eliminate the contamination source and allow restoration by natural flushing, dilution, and geochemical or biological reactions. An accurate estimation of the time required to restore water quality in aquifers through natural flushing will be helpful to the decision-making on management options.

Continuous leaching of chemical contaminants from landfills will remain a long term problem in many communities in the state. The largest landfill in the New England region is the Central Landfill in Johnston, Rhode Island. Part of this landfill also contains hazardous waste. Three waste incinerators have been proposed for the State of Rhode Island. The incinerator residue and ash will be disposed of in the Central Landfill. The quality of leachate from the residue/ash landfill with or without mixing in with municipal solid waste is of concern. It may contain volatile organics and heavy metals, leading to aquifer contamination. A study characterizing the residue/ash and its leachate will be very helpful in landfill management.

Strategies for protecting the water quality in the state have been concentrated on protective zones surrounding surface reservoirs and local restrictions on development over major aquifers. These efforts are being compromised by the expansion of intensive land uses in Rhode Island adjacent to tributaries and aquifer recharge areas. Presently, not much is known about the fate of materials which are washed off land surfaces by rain water. An emerging technique for controlling the movement of sediments, nutrients, heavy metals, and organic compound over land is the use of vegetative buffer strips. Small
strips of grass or other vegetation can be used to trap pollutants moving from land areas before they enter water bodies. The maintenance of riparian filter strips was adopted as a "best management practice" by the U.S. Department of Agriculture and is recommended for use as a complement to structural storm water control devices in Rhode Island. The scientific basis for the effectiveness of buffer strips needs study. There is a great need for research to determine if the current guidelines for vegetative buffer strip use is appropriate.

Removal of heavy metals and cyanide from wastewaters remains a problem in Rhode Island, particularly in the Providence area where hundreds of firms with plating activities are located. The existing pretreatment program is effective only in curbing the discharge of these pollutants from large firms. Unfortunately, most plating firms are small and reluctant to apply treatment to their wastes prior to their discharge to the sewer line. There is a great need to develop a technology for heavy metal and cyanide treatment for small as well as large firms in the state. Particularly useful would be the recovery of the heavy metal for reuse.
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PROGRAM GOALS AND PRIORITIES

The research needs on water resources in the New England region as identified by the New England Council of Water Center Directors have been:

Groundwater Management
- Location and extent of groundwater supplies
- Recharge characterization
- Rural and small town water supply systems
- Sources of toxic materials
- Fate and transport of chemicals

Surface Water Management
- Land use/hydrology interactions
- Water reuse and conservation
- Eutrophication
- Acid precipitation
- Watershed management

Ecological and Health Relationships
- Wetland ecology
- Effects of chemicals in water on human health

Institute Frameworks
- Water use planning and management
- Water allocation and reallocation
- Conflict resolution among competing users

Guided by these research needs, the Rhode Island Water Resources Center developed its program goals to meet some of these research needs as well as to transfer the information water resources research/management/education to the public. Both the State Advisory Committee and the University Water Resources Coordinating Committee for the Center were consulted to finalize the research topics for the FY-1988 program. Groundwater research remained to be an important part of the program. However, strong efforts and considerable resources were put into surface water quality and water quality control research.

Project proposals were reviewed and selected on the criteria of (1) satisfying the state and regional research needs, (2) technical competency, and (3) reasonable budget.

Two projects related to groundwater quality problems met the identified research needs and were selected for the FY-1988 program. Project 02 on Uranium-Thorium Concentrations in Bedrock and Surficial Materials: Primary Sources of Radon in Rhode Island Aquifers used the epithermal neutron activation technique developed and perfected in the previous year to quantitatively determine U and Th concentrations in geological
material. The final results exhibited a considerable range in U and Th levels, the lower concentrations were consistently found in the Precambrian rocks of calcalkaline affinity and the Hope Valley gneissic rocks, with U levels ranging from 1.4 to 4 ppm and Th from 5.0 to 21.3 ppm. Associated volcanic rocks levels ranged from 2.0 to 3.2 ppm U and 9.3 to 12.0 ppm Th. The Permian aged Narragansett Pier Granite was found to contain low to moderated U, ranging from 2.7 to 5.7 ppm, but found to be enriched to Th, ranging from 22.0 to 103.2 ppm. The bimodal distribution of U and Th suggested that the U may have been mobilized and redepocitated in rocks. U and Th were found higher among the alkalic rocks. The plutonic rocks ranged from 2.2 to 22.8 ppm with the highest U consistently found in the peralkaline Rhode Island Quincy Granite and one-feldspar hypersolves Scituate Granite. The clastic sediments of the Narragansett Basin yield only low to moderate U and Th values. The information is very helpful in guiding the future radon programs in the State of Rhode Island to identify possible hot spots.

Project 03 on Stochastic Study of the Natural Flushing of Contaminants from Aquifers used a two-dimensional Galerkin finite-element procedure and the Monte Carlo simulation in order to consider the stochastic nature of the source/sink term. The procedure also required the modeling of the occurrence of rainstorms by a Poisson process and the amount of rainfall in each storm by an exponential probability distribution. Numerical errors resulting from the solution of the partial differential equation were related to the space and time increments and therefore a careful discretization of the space and time dimensions could keep the errors within tolerable limits. The model provides information on how an estimation of the time required for restoring water quality in aquifers through natural flushing can be carried out.

Project 04 on A Microbial Method for Removal of Metals, Cutting Oils, and Cyanide from Polluted Water, Phase II, successfully isolated a plasmid which was cloned into a bacterium E. coli HB101. The cloned bacterium has a much higher resistance to the toxic metal cadmium than ordinary E. coli. A model system inoculated with Arthrobacter SL-1 suspended in Pipes buffer at pH 5.5 has been successfully tested to remove Pb, Cd, Ni, and Zn from 94 to 98% removal on a continuous flow condition. The project information is useful for the design of a biological treatment system for heavy metal removal from industrial wastewaters.

Project 05 on Evaluating Plants for Nutrient Retention in Vegetative Buffer Strips studied the kinetic parameters for nitrate absorption by selected plant species. Rates of nitrate absorption were found to be consistently low during the first 30 to 60 minutes, followed by high rates of absorption between 90 and 180 minutes which gradually declined later. Experiments have been modified so that any initial variations in the absorption rate would not compromise the accurate estimation of the linear rate constant, resulting in good uptake kinetic curves. The research is continuing and good results from all the grasses studied will be available in a couple of months.

Project 06 on Microbial Processes Controlling the Fate of Nitrogen in Vegetative Buffer Strips, similar to Project 05, studied the nitrogen changes in vegetative buffer zone
material. The final results exhibited a considerable range in U and Th levels, the lower concentrations were consistently found in the Precambrian rocks of calcalkaline affinity and the Hope Valley gneissic rocks, with U levels ranging from 1.4 to 4 ppm and Th from 5.0 to 21.3 ppm. Associated volcanic rocks levels ranged from 2.0 to 3.2 ppm U and 9.3 to 12.0 ppm Th. The Permian Anadale Narrangansett Pier Granite was found to contain low to moderate U, ranging from 2.7 to 5.7 ppm, but found to be enriched to Th, ranging from 22.0 to 103.2 ppm. The bimodal distribution of U and Th suggested that the U may have been mobilized and reprecipitated in rocks. U and Th were found higher among the alkaline rocks. The plutonic rocks ranged from 2.2 to 22.8 ppm with the highest U consistently found in the peralkaline Rhode Island Quincy Granite and one-folddspars hypehrsilitite Scituate Granite. The clastic sediments of the Narrangansett Bay yield only low to moderate U and Th values. The information is very helpful in guiding the future radon programs in the State of Rhode Island to identify possible hot spots.

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Project 06 on Microbial Processes Controlling the Fate of Nitrogen in Vegetative Buffer Strips, similar to Project 05, studied the nitrogen changes in vegetative buffer zone but concentrated on the microbial processes instead of uptakes by vegetation. Denitrification, the main microbial process to remove nitrogen, was found to proceed at a rate of 7859 g N/ha.day for tall fescue and 4537 g N/ha.day for reeds canary grass, and 31 and 375 g N/ha.day respectively for well drained and poorly drained forest plots. Adding lime to raise the pH of the soils in the forest plots did not increase the denitrification rate as expected. Immobilization was found to be only a temporary sink of nitrate and any N that was immobilized could be subsequently released or mineralized. Mineralization was highest in the poorly drained forest soil and was higher in the reed's canary grass than in the tall fescues soil. The findings of Projects 05 and 06 are useful to provide guidance to planning agencies in selecting, designing, and managing of vegetative buffer strips for nutrient removal.

Project 07 on Study of Fly Ash and Bottom Ash and Their Leachate Characteristics in a Simulated Landfill Condition, was a privately funded project started in December, 1987. The mixed ash from an municipal solidwaste incinerator was found to contain on the average 6.5 ppm Pb and 0.85 ppm Cd using the EPA's EP extraction procedure, and 1.10 ppm Pb and 1.25 ppm Cd using the EPA's TCLP extraction procedure. Column studies showed that simulated landfill condition with artificial acid rainfalls yield very low concentrations of Pb and Cd in the leachate. However, large amounts of organics, chloride, dissolved solids and other chemicals were found in the leachate from the ash column or the ash/MSW mixed columns. A computer HELP Model was found to be useful to predict the quantity of leachate from landfills. The results are very useful to the Rhode Island Solid Waste Management Corp. which manages a Central Landfill and will be designing an ash landfill in the near future.

Project 02 on Simultaneous Removal of Cyanide and Heavy Metals from Industrial Process Wastewaters was funded entirely by the Rhode Island State Department of Environmental Management, starting December, 1988. Unlike Project 04 which used a microbial system, Project S2 used a physical-chemical method of electrofloation to concentrate the heavy metals from wastewaters. The concentrated heavy metal in the form of a scum could be dissolved in acid solution and plated out. Chlorine was generated from the brine solution anode of the cyanide simultaneously with metal electrofloation. The project will be carried into the FY-1989 program.

Sources and level of funding for the various projects including the information transfer activities are listed in Table 1 on the next page.
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| 02 | **$11,350**  
Uranium-Thorium Concentrations in Bedrock and Surficial Materials: Primary Sources of Radon in R.I. Aquifers  
**$29,363**  
University of R.I. |
| 03 | 14,005  
Stochastic Study of the Natural Flushing of Contaminants from Aquifers  
35,095  
University of R.I. |
| 04 | 14,000  
A Microbial Method for Removal of Metals, Cutting Oils, and Cyanide from Polluted Water  
37,035  
University of R.I. |
| 05 | 9,700  
Evaluating Plants for Nutrient Retention in Vegetative Buffer Strips  
23,531  
University of R.I. |
| 06 | 9,634  
Microbial Processes Controlling the Fate of Nitrogen in Vegetative Buffer Strips  
15,078  
University of R.I. |
| S1 | 11,250  
Study of Fly Ash and Bottom Ash and Their Leachate Characteristics  
250  
RI Solid Waste Management Corp.  
University of R.I. |
| S2 | 19,947  
Simultaneous Removal of Cyanide and Heavy Metals from Industrial Process Wastewaters  
4,930  
RI Dept. of Environmental Management, University of R.I. |
| 22 | 15,250  
Information Transfer Activities  
(See description later in report)  
27,875  
University of R.I. |

Center Administration  
(Including publication of newsletters)  
30,591  
53,798  
US Geological Survey  
University of R.I. |

*Ending May 31, 1989*
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**Ending May 31, 1989**

**PROJECT NUMBER:** 02

**START:** 6/1/87

**END:** 5/31/89

**TITLE:** URANIUM CONCENTRATIONS IN BEDROCK AND SURFICIAL MATERIALS: PRIMARY SOURCES OF RADON IN RHODE ISLAND AQUIFERS

**INVESTIGATOR:** O. DON HERMES, GEOLOGY DEPARTMENT, UNIVERSITY OF RHODE ISLAND, KINGSTON, RHODE ISLAND 02892

**COWWR:** 02K

**CONGRESSIONAL DISTRICT:** SECOND, RI

**KEY WORDS:** GEOCHEMISTRY, ISOTOPES, DATA, WATER QUALITY, PUBLIC HEALTH

**PROBLEM AND RESEARCH OBJECTIVES:**

The occurrence of elevated levels of radon gas in indoor air has, in recent years, become recognized as a leading cause of lung cancer. The Environmental Protection Agency now estimates that up to 20,000 lung cancer deaths per year in the United States may be attributed to long term exposure to radon and its decay products. Radon-222 (^{222}\text{Rn}) , the isotope which poses the health risk, is the only gas in a long series of decays originating with the decay of ^{238}\text{U} . Primary ^{238}\text{U} comprises more than ninety-nine percent of the naturally occurring uranium isotopes:

\[ ^{238}\text{U} \rightarrow ^{234}\text{Th} \rightarrow ^{234}\text{Pa} \rightarrow ^{234}\text{U} \rightarrow ^{234}\text{Th} \rightarrow ^{226}\text{Ra} \rightarrow ^{222}\text{Rn} \]

^{222}\text{Rn} decays with a half life of 3.8 days, undergoing several rapid disintegrations leading to ^{210}\text{Pb} , which has a half life of 22 years. The ^{210}\text{Pb} ultimately decays to the stable lead isotope ^{208}\text{Pb} . The primary geologic sources of uranium, and hence radon, are igneous rocks, especially alkali enriched granite rocks, and sedimentary and metamorphic materials subsequently derived from these igneous protoliths.

Radon is an inert, water soluble gas which readily enters the atmosphere or groundwater and is formed as a result of alpha-decay of the parent isotope, ^{226}\text{Ra} . Previous studies (King and others, 1982; Hall and others, 1987) have shown that high radon levels in groundwater exhibit a positive
correlation with high radium levels and that both radon and radium isotopes may correlate with high U in the geologic materials that comprise the aquifers. The health risk of radon-rich waters in domestic wells is two-fold. Ingestion has been associated with increased risk of stomach cancer (Donahue, 1984). Of greater concern is the inhalation of the radioactive gas which may result when $^{222}$Rn partitions into the air from the water supply. Alpha-decay of this inhaled $^{222}$Rn results in lung tissue damage and possibly lung cancer.

Known petrologic and geochemical characteristics of geological materials in Rhode Island suggest anomalously high concentrations of radioactive parent nuclide uranium-238. The primary objective of this project has been to quantitatively determine uranium concentrations in the states’s crystalline bedrock, metasedimentary rocks of the Narragansett Basin, and surficial glacial deposits, in an attempt to identify and delineate geographic areas which are potential sinks for the daughter product radon in both groundwater aquifers and indoor air.

Although uranium is present in nearly all geological materials, levels are usually so low that trace level analytical methods are necessary to determine it’s concentration. The determination of U contents requires the establishment of an analytical technique not previously available to the URI community. The method chosen for this study is a modification of traditional neutron activation analysis known as epithermal neutron activation analysis. As a result of the work accomplished in this project, such analyses may now be routinely performed for the first time at the Rhode Island Nuclear Science Center. The set up of this method entails the development of a suitable procedure based on trial irradiations, experimentation, and on reviews of recent related literature with the aim of minimizing analytical error and optimizing detection limits. Thus, the establishment of this technique constituted a major early effort of this project and is a valuable by-product of our work.
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METHODOLOGY:

EPITHERMAL NEUTRON ACTIVATION ANALYSIS

The basic principle of neutron activation analysis is that a stable isotope, when bombarded
by neutrons (generated in a nuclear reactor), undergoes a nuclear transformation producing a
radioactive nuclide (Lyon, 1964). The emanations from this formed radionuclide (gamma-rays)
are measured using radiation detection instruments, such as scintillation counters, thus allowing
quantitative determination of the elemental composition of the sample before irradiation.

The neutron energy distribution in the nuclear reactor core is divided into three neutron flux
components. A fast neutron component comprises those neutrons above about 0.1 MeV; an
epithermal neutron component ranging from 0.2 ev to 0.1 MeV; and a thermal neutron component
consisting of neutrons with energy below 0.2 ev. In most cases irradiation with the whole of the
reactor’s spectrum is performed, where the vast majority of the neutrons fall in the thermal energy
range. Most nuclides capture thermal neutrons with a relatively high probability (cross sections)
and epithermal and fast neutrons with a very low probability. Thus, traditional activation analysis
is used successfully and routinely in the quantification of a large number of elements in a geologic
matrix, but is much less effective in characterizing levels of elements such as U and Th.

A variation of traditional neutron activation, epithermal neutron activation, is necessary when
determining concentrations of U in geologic materials for two reasons. First, the ratio of these trace
elements to the matrix elements (ie. Al, Na, Fe) present in geologic material is extremely small.
Second, as previously stated, a nuclide must capture an incoming neutron in order to undergo a
nuclear transformation. Uranium-238, unlike the majority of nuclides in geological material, has
a relatively low probability of capturing thermal neutrons and has a greater preference for the
epithermal component of the flux. It is essential to optimize the number of collisions, as the signal
generated by the newly formed nuclide, and subsequently measured, is directly proportional to the
number of atoms that react with the incoming neutrons.
Epithermal neutron activation analysis allows the activation rate of nuclides with high epithermal cross sections to be enhanced relative to other nuclides by shielding the rock sample from the component of thermal neutrons. The selective penetration of neutrons is accomplished by placing a cadmium shield between the incoming neutrons and the rock sample. Cadmium metal has an extremely high absorption cross-section in the thermal neutron region and, as such, is well suited in preventing the transmission of thermal neutrons. When a sample is irradiated behind a cadmium cover, virtually all the thermal neutrons are excluded (absorbed by the cadmium) and only those neutrons with energies greater than 0.4 eV will pass through, contributing to the activation process (Steinnes and Brune, 1969). For U and additional elements which include Th, Ta, and Hf, the fraction of activations by epithermal neutrons exceeds that due to thermal neutron capture. Therefore, for complex matrices such as geologic samples, the activity level of the abundant light matrix radionuclides such as $^{24}\text{Na}$ (half-life=15h) and $^{56}\text{Mn}$ (half-life=2.58h) decreases to a much greater extent than the activities of U (Meyer, 1971; Parry, 1982). As a result, the radioactivity level of the U is enhanced permitting detection to approximately 0.1 ppm levels.

PROCEDURE

A broad spectrum of volcanic and plutonic rocks, representative of the major rock groups in Rhode Island, have been analyzed for U and Th content. Knowledge of Th concentrations permits calculation of a Th/U ratio which can offer insight into initial redox conditions of the magma body, or suggest secondary enrichment or depletion of U in a rock. Therefore Th was also measured using the epithermal enhancement method (as with U, it has a high probability of capturing epithermal neutrons). After field collection, the rocks samples are ground and prepared for analysis using rock grinding and powdering equipment in the Geology Department. Routine major and trace chemistry analyses are done, as needed, on a Kevex ED-XRF system that is fully operational in the geology department.

Splits of each powdered sample are analyzed for U and Th by epithermal neutron activation techniques at the Rhode Island Nuclear Science Center. In preparation for each irradiation,
Epithermal neutron activation analysis allows the activation rate of nuclides with high epithermal cross sections to be enhanced relative to other nuclides by shielding the rock sample from the component of thermal neutrons. The selective penetration of neutrons is accomplished by placing a cadmium shield between the incoming neutrons and the rock sample. Cadmium metal has an extremely high absorption cross-section in the thermal neutron region and, as such, is well suited in preventing the transmission of thermal neutrons. When a sample is irradiated behind a cadmium cover, virtually all the thermal neutrons are excluded (absorbed by the cadmium) and only those neutrons with energies greater than 0.4 ev will pass through, contributing to the activation process (Steinnes and Brune, 1969). For U and additional elements which include Th, Ta, and Hf, the fraction of activations by epithermal neutrons exceeds that due to thermal neutron capture. Therefore, for complex matrices such as geologic samples, the activity level of the abundant light matrix radionuclides such as \(^{24}\)Na (half-life=1.5h) and \(^{58}\)Mn (half-life=2.58h) decreases to a much greater extent than the activities of U (Meyer, 1971; Parry, 1982). As a result, the radioactivity level of the U is enhanced permitting detection to approximately 0.1 ppm levels.

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Splits of each powdered sample are analyzed for U and Th by epithermal neutron activation techniques at the Rhode Island Nuclear Science Center. In preparation for each irradiation, approximately 300 mg of powdered rock sample is weighed into 2/5 dram polyethylene capsules and heat sealed to avoid post-irradiation spillage of the radioactive sample. A flux monitor is necessary for each sample and consists of a 5 cm length of iron wire. The wire serves to record the neutron flux on each sample, as this flux is not uniform among all samples. Each cleaned and weighed iron wire is wrapped and taped around a sealed sample capsule.

The samples with their respective flux wires are then placed in one of two cadmium vials designed to hold nine samples each. Each Cd vial measures 7.75 cm in height and 2.92 cm in diameter. These two Cd vials were intem placed in a rabbit and irradiated at a flux of \(4 \times 10^{12}\) n/cm²·sec for three hours. Irradiations are done in the late afternoon on any given day to ensure that the rabbit remains in the reactor overnight following shutdown. This necessary precaution allows the Cd isotopes produced sufficient decay time before being released to the rabbit station the following day.

After removal from the rabbit, the samples are separated from the encapsulating cadmium, thus immediately lowering exposure levels, and stored in the appropriate facility in the reactor. The samples and standards are measured for their gamma-ray spectra on a lithium drifted germanium detector (Ge(Li)) with an energy resolution of 0.5 KeV/channel and an efficiency of 21%. Counting of each of the 18 samples is done seven days after irradiation in order to obtain the gamma-spectra indicative of \(^{238}\)U. The samples are counted a second time 18 days following irradiation for the spectra resulting from the \(^{238}\)Th in the sample. In both cases the 18 samples are placed in an automatic sample changer and counted for 2 hours each. Each of the spectra are recorded and appropriate data stored on magnetic tape.

The gamma-ray spectra are then evaluated using the total peak area method. A peak height analysis program is run which identifies and labels the energy (in KeV units) of each peak and the corresponding intensity (counts/second) for each of the spectra. The data from the peak height analysis program are then entered into the spreadsheet program QUATTRO where a program
has been written specifically to convert peak intensities corresponding to U and Th in the sample to final concentrations (ppm). Thus, approximately one month elapses between the time of irradiation and final compilation of results for each irradiation.

**PRINCIPAL FINDINGS AND SIGNIFICANCE:**

A major early effort of our work has been to develop and perfect the above analytical technique to quantitatively determine U and Th concentrations in geological material. Compared to several alternative analytical techniques for U and Th analysis, the chosen method requires a simpler set-up, less preparation per sample, and has been proven quantitatively accurate and statistically reproducible. This method is now of potential use to other researchers and constitutes a valuable by-product of our work.

Results of U and Th from a broad group of plutonic and volcanic rocks in Rhode Island and adjacent Connecticut and Massachusetts are presented in Tables 1 and 2, respectively. U and Th values from selected samples of metasedimentary rocks of the Narragansett Basin are shown in Table 3. A generalized bedrock map of southeastern New England (Figure 1) shows the prominent rock units in Rhode Island. The bedrock in the state is separable into two distinct assemblages with different late Precambrian and Paleozoic components. The boundary between these two terranes is a zone of ductile deformation termed the Hope Valley Shear Zone (O'Hara and Gromet, 1985). The western Hope Valley terrane is dominated by pervasively deformed Precambrian gneisses of granitic composition. The crystalline rocks of the eastern Esmond-Dedham Terrane may be divided into two broad suites; calcalkaline and alkaline complexes, with further subdivision based on age.

Trace element data from plutonic and volcanic rocks clearly discriminate the two mentioned suites (Hermes and Murray, in press). Calcalkaline rocks, associated with island arc processes, and typical of compressional plate margins, are chemically distinct from rocks of alkaline affinity. The alkaline suites are enriched in large ion lithophile elements such as Y, Rb, Nb, Th and U and are thought to represent within plate, anorogenic plutons. Calcalkaline rocks are typically lower in these high field strength elements.
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The calcalkaline plutonic and volcanic rocks have Precambrian and Permian representatives. The Precambrian calcalkaline rocks predominantly include plutonic basement complexes such as the Esmond Granite and Dedham Granodiorite. Minor associated volcanics are the Hunting Hill Greenstone, and Lynn and Mattapan Volcanics. The younger calcalkaline suite of rocks is the Permian aged Narragansett Pier Granite, a large batholith located along Rhode Island’s southern coast. This granite locally intrudes Carboniferous metasedimentary rocks of the Narragansett Basin. These basin rocks are interpreted as non-marine, primarily a braided stream complex.

The alkalic units include the Devonian aged Scituate Granite and related rocks, and comprise a significant portion of the state. This suite may be divided into a two-feldspar subsolvus granite to the west and a one-feldspar hypersolvus granite to the east and northeast. An additional alkaline unit is the Carboniferous aged Rhode Island Quincy Granite, a small peralkaline pluton located in the northeast corner of the state. Alkaline volcanic counterparts include the Spencer Hill and Wamsutta volcanics.

While the final results exhibit a considerable range in U and Th levels, the lower concentrations are consistently found in the Precambrian rocks of calcalkaline affinity and the Hope Valley gneissic rocks. Among the plutonic suites, U levels range from 1.4-4 ppm and Th from 5.0-21.3 ppm (Table 1). Associated volcanic rocks overlap these concentrations ranging from 2.0-3.2 ppm U and 9.3-12.0 ppm Th, excluding the Hunting Hill Greenstone which is basaltic and expected to contain significantly less U and Th as compared to the more felsic rocks (Table 2).

The Permian aged Narragansett Pier Granite is peraluminous and distinct from the more meta-aluminous Precambrian calcalkaline lithologies. It consists of two distinct and mappable facies recognized on the basis of textural and color variations. A pink facies comprises the bulk of the pluton while a white or leucocratic facies exists in the eastern corner of the granite body. The distribution of U and Th in these rocks tends to be bimodal (Table 1). Six of the seven pink facies rocks sampled yielded low to moderate U and ranged from 2.7 to 5.7 ppm. The same samples were generally found to be enriched in Th with levels from 22.0 to 103.2 ppm, the highest concentration
found in this study to date. The three leucocratic samples are more enriched in U relative to the pink facies (7.6-13.1 ppm), yet contain significantly less Th. The bimodal distribution of U and Th suggests that the U may have been mobilized and reprecipitated in rocks of the white facies and is possibly related to the reduced nature of the adjacent sedimentary rocks of the Narragansett Basin which are locally rich in carbonaceous material.

Clearly concentrations of both U and Th are higher among the alkaline rocks sampled. The plutonic rocks range from 2.2 to 22.8 ppm with the highest U consistently found in the peralkaline Rhode Island Quincy Granite and one-feldspar hypersolvus Scituate Granite. The elevated U and Th values are consistent with previous geochemical and petrological work in this region. The alkaline rocks of southeastern New England are known to be higher in trace elements Rb, Zr, Nb, and Zn, and lower in Sr and Ba compared to the Precambrian calcalkaline unite (Hermes and Zartman, 1985; Hermes and Murray, in press). Commonly, granitic rocks enriched in these high field strength elements also show high concentrations of U and Th (Harris and Marriner, 1980), an observation also supported by the data of this study.

The clastic sediments of the Narragansett Basin yielded low to moderate U and Th values (Table 3). The samples analyzed were from the Rhode Island Formation, the most extensive formation, comprising more than eighty percent of the basin. Sedimentary samples were collected from two of the most populated areas in the state, Cranston and North Providence.

It remains unclear if radon levels might directly relate to such diverse distributions of U in bedrock as observed in this study. It is clear, however, that knowledge of U levels in bedrock and the distribution geographically of U is crucial to the understanding of radon occurrence and mobility in the groundwater environment.

PUBLICATIONS AND PROFESSIONAL PRESENTATIONS:


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M.S. THESIS: Nancy Nevins, expected completion fall 1989

**REFERENCES CITED**


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### Table 1. Results from range of plutonic lithologies (NPG=Narragansett Pier Granite)

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### Table 2. Results from a range of volcanic lithologies

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### Table 3. U and Th results from sedimentary rocks of RI Formation, Narragansett Basin

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Figure 1. Generalized geologic map of southeastern New England emphasizing the volcanic and plutonic rocks referred to in this report. Geology after Quinn [1971], Zen [1983], Hermes and Zartman [1985], and O'Hara and Gromet [1985].
SYNOPSIS

Project Number: 03

Start: 6/1/88
End: 5/31/89

Title: Stochastic study of the natural flushing of contaminants from aquifers.

Investigators: Sau-Lon James Hu
Department of Ocean Engineering
University of Rhode Island.

Cheng-Jung Chang
Department of Civil Engineering
University of Rhode Island.

COWVR: 02P
Congressional Dist: 2

Key Words: Groundwater Modeling, Numerical Analysis, Rainfall, Solute Transport, Stochastic Hydrology.

Problem & Research Objectives:

Groundwater, which is a major source of water supply in the United States, is facing severe quantity and quality...

Figure 1. Generalized geologic map of southeastern New England emphasizing the volcanic and plutonic rocks referred to in this report. Geology after Quinn (1971), Zen (1983), Hermes and Zartman (1985), and O'Hara and Gromet (1985).
problems. Once contaminated, the options available for its use are both limited and costly. A contaminant usually enters groundwater from the surface of the land, percolating down through the aerated soil and the non-saturated zone. Once a contaminant reaches the aquifer, its movement is determined to some extent by its solubility in water. In considering the many different sources and causes of groundwater contamination, it becomes imperative that no simple solution can address this problem adequately and comprehensively.

Contamination has occurred in most regions of the country and will probably continue to occur. In Rhode Island, more than a dozen contaminations due to spills and leaks of organic materials have been reported in the past few years. The attempt to determine the extent of contamination in polluted area is being undertaken by the Rhode Island Department of Environmental Management. In response to public demands for positive action in cases where groundwater contamination threatens public health, aquifer cleanup programs are being required.

Once contamination is detected, there is a choice as to whether to take action and, if so, what form that action should take. Aquifer rehabilitation is feasible in some cases, but it is expensive and time-consuming with no guarantee of complete success. Because of the difficulty and uncertainty of remedial action, protection of useful,
problems. Once contaminated, the options available for its use are both limited and costly. A contaminant usually enters groundwater from the surface of the land, percolating down through the aerated soil and the non-saturated zone. Once a contaminant reaches the aquifer, its movement is determined to some extent by its solubility in water. In considering the many different sources and causes of groundwater contamination, it becomes imperative that no simple solution can address this problem adequately and comprehensively.

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Once contamination is detected, there is a choice as to whether to take action and, if so, what form that action should take. Aquifer rehabilitation is feasible in some cases, but it is expensive and time-consuming with no guarantee of complete success. Because of the difficulty and uncertainty of remedial action, protection of useful, potable aquifers from contamination is a better strategy than curative effects. The appropriate response to a groundwater-pollution problem will depend upon the physical characteristics of the site and the nature of the contamination. The selection of the best approach for restoring water quality in aquifers requires the ability to predict changes in flow and chemical concentration in the aquifer for each possible management alternative. This in turn requires both adequate field data to describe the aquifer systems and the development of accurate simulation models to define the groundwater flow system, the pollutant-transport mechanism, and the nature and rates of chemical, physical and biological reactions. In many cases, restoration is so expensive that cleanup is not considered to be economically feasible. Among many management options for restoring water quality in aquifers, one is to eliminate the source of contamination but allow restoration to proceed only through natural flushing, dilution, and geochemical or biological reactions. Virtually all the water in the earth's crust will cycle back to the biosphere. However, the time for the cycle to be completed varies enormously — from days to tens of thousands of years. Apparently, an accurate estimation of the required time for restoring water quality in aquifers through natural flushing is helpful to the decision-making on the management options.
The primary objective of this research is to develop a numerical model for predicting the time required for restoring water quality in contaminated aquifers through natural flushing.

Methodology:

The movement of contaminants in groundwater is a particularly active area of research. Most attempts at quantifying contaminant transport have relied on a system of some form of a well-known governing equation referred to as the advection-dispersion equation which may be written in its most general form:

\[
\frac{\partial}{\partial x_i} \left( D_{ij} \frac{\partial c}{\partial x_j} \right) - \frac{\partial}{\partial x_i} \left( c \, v_i \right) \right) - \frac{c'}{n} \, \frac{W}{n} + \sum_{k=1}^{s} R_k = \frac{\partial c}{\partial t}
\]

where \( c \) is the solute concentration and \( D_{ij} \) is the coefficient of dispersion (the \( i,j \) indices refer to cartesian coordinates.). \( c' \) is the concentration of a solute in a source or sink fluid, \( v \) denotes the average linear velocity of groundwater, and \( W \) is the volume flow rate of the sink or source fluid per unit volume of porous material. In the chemical-reaction term, \( R_k \) is the rate of production.
The primary objective of this research is to develop a numerical model for predicting the time required for restoring water quality in contaminated aquifers through natural flushing.

**Methodology:**

The movement of contaminants in groundwater is a particularly active area of research. Most attempts at quantifying contaminant transport have relied on a system of some form of a well-known governing equation referred to as the advection-dispersion equation which may be written in its most general form:

\[
\frac{\partial}{\partial t} \left( D_{ij} \frac{\partial c}{\partial x_j} \right) - \frac{\partial}{\partial x_i} (c V_i) = - \frac{\partial}{\partial x_i} (c R_k) = \frac{\partial c}{\partial t}
\]

where \( c \) is the solute concentration and \( D_{ij} \) is the coefficient of dispersion (the \( i,j \) indices refer to cartesian coordinates.), \( c' \) is the concentration of a solute in a source or sink fluid, \( v \) denotes the average linear velocity of groundwater, and \( W \) is the volume flow rate of the sink or source fluid per unit volume of porous material. In the chemical-reaction term, \( R_k \) is the rate of production of the solute in reaction \( k \) of \( s \) different reactions. The average linear velocity \( v \) of groundwater may be written as

\[
v = KI/n
\]

where \( K \) is hydraulic conductivity, \( I \) is the head gradient, and \( n \) is the effective porosity. The sink/source term \( W \) can include well discharge, recharge from precipitation, and evapotranspiration. In the model, \( W \) is computed as

\[
W = Q_w - q_{re} + q_{et}
\]

where \( Q_w \) = well discharge

\( q_{re} \) = recharge flux

\( q_{et} \) = evapotranspiration flux

In this study, for evaluating the natural flushing rates of contaminants from aquifers, the chemical reaction term will be ignored and the sink/source term will be modeled as a stochastic process.

**Principal Findings & Significance:**

A two-dimensional Galerkin finite-element procedure is used in this research. In order to consider the stochastic nature of the source/sink term, Monte Carlo
simulation is adopted. It is realized that Monte Carlo techniques become particularly useful when the relationship among variables are complicated functions.

Assume that recharge from precipitation is mainly due to rainfall. It has been proposed that an event-based rainfall simulation model can be constructed by modeling the occurrence of rainstorms by a Poisson process and the amount of rain in each storm by an exponential probability distribution. Let the number of rainy weeks \( N \) be Poisson-distribution with mean \( \mu \), and the rainfall in a rainy week, \( R_i \), be exponentially distributed with parameter \( \lambda \) (mean = \( 1/\lambda \)). Denoting \( T \) as the total annual rainfall, the relationship between \( T \), \( N \) and the \( R_i \)'s is:

\[
T = \sum_{i=1}^{N} R_i
\]

That is, \( T \) is the sum of a random number of random variables. For convenience, it is assumed that rainfall in rainy weeks are identically distributed and mutually independent. An initial study via Monte Carlo simulations has shown that a significant difference occurs in repeated simulations. For obtaining reliably statistical data, a huge number of simulations should be carried out.

Numerical errors arise from the numerical solution of the partial differential equation are related to the space
simulation is adopted. It is realized that Monte Carlo techniques become particularly useful when the relationship among variables are complicated functions.

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Numerical errors arise from the numerical solution of the partial differential equation are related to the space and time increments; these errors can be kept within tolerable limits through careful discretization of the space and time dimensions. The Galerkin's procedure is well-suited to solve solute-transport problems, because of its versatility in handling irregular geometries. Although advective-dispersive transport in groundwater system is inherently three-dimensional, due to that a great deal of computational time is needed, numerical simulation of field-contaminant plumes are suggested to be done in one or two dimensions.

Publications & Professional Presentation:

In preparation.
SYNOPSIS

Project Number: 04 Start 6/1/88
End 5/31/89

Title: A Microbial Method for Removal of Metals, Cutting Oils & Cyanide from Polluted Water - Phase II

Investigators: Dr. R. W. Traxler, University of Rhode Island
Dr. Tung-Ching Lee, University of Rhode Island
Dr. D. R. Nelson, University of Rhode Island

COWRR: 05D Waste Treatment Process

Descriptors: Bacteria, Biodegradation, Heavy Metals, Waste Disposal, Pollution Control

Problem & Research Objectives:

Rhode Island regulations limiting the discharge of toxic metals and cyanide into public sewers have been in effect for five years, but the majority of affected platers and finishers are not in compliance with these regulations. Many of the larger firms meet discharge standards or are expected to do so in the near future, but the smaller companies have not had the resources to effectively meet these standards.

The magnitude of the problem is seen by the amount of heavy metal entering the Narragansett Bay Commission sewer system in recent years. The peak was in 1981 with 956,099 pounds release with a drop in 1985 to 409,657 pounds. The interim goal is to reduce this volume to about 200,000 pounds, within a year. The existing technology for solution of this problem by chemical means is expensive. One of the larger companies was forced to spend $500,000 for a pre-treatment system. This type of a solution to the problem is beyond the capability of the smaller operator who does not have the capital resources for even a 5th of this type of investment. The ultimate result is that without a less expensive system these small companies will be forced out of business. This project is aimed at the small operation to provide to these companies a relatively simple, inexpensive but effective means of pollution control. The project, while of extreme potential value to Rhode Island, can also be applied to the same problem in other states.

Objective for FY-1988, Phase II

1. Evaluate assays for metal resistance.

2. Develop a system to transfer genetic resistance of a metal
SYNOPSIS

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Objective for FY-1988, Phase II
1. Evaluate assays for metal resistance.
2. Develop a system to transfer genetic resistance of a metal from one bacterium to another.
3. Test a model system for metal bioaccumulation.
4. Investigate cyanide utilization.

Principal Findings & Significance

1. Objective 1.

The conventional agar plate assay whereby paper discs containing various concentration of metal are placed on a seeded agar plate, incubated and the zone of inhibition measured were used with the various metals studied in this project. It was possible to obtain concentration dependent values for inhibition. Assays which determine the minimal inhibitory concentration of a metal using V-B broth were compared to the agar assay and were found to give lower (10-15 fold) inhibition concentrations. These data indicate that agar systems cannot be used to assay metal toxicity and resistance.

2. Objective 2.

A plasmid has been isolated and cloned into E. coli HB101 which increases the resistance of the clone to Cd.

3. Objective 3

The model system (Figure 1) has been tested with Arthrobacter SL-1 suspended in Pipes buffer at pH 5.5.

The results of a static system are shown in Table 1, in which the metal removed from the waste water ranged from 48 to 98% for the individual metals. Each metal was initially present in the waste at 50 ppm, therefore, the waste contained a total of 400 ppm of metal ion. The 4 main target metals, Pb, Cd, Ni, and Zn ranged from 94 to 98% removal. After treatment, the cells are recovered by centrifugation to yield a concentrated slurry of digestion and the metal precipitated as insoluble salts.

In the model system testing we used a 900 ml reactor volume containing 24.7 mg/ml of Arthrobacter SL-1 in Pipes buffer at pH 5.5, agitation at 200 rpm and temperature at 30 C. The waste was flowed through the system at a Dilution Rate of 0.2 for a total treatment time of 240 minutes. The effluent metal levels are shown in Figure 2. It is important to note that the 240 minute value for Ni only represents 0.2 ppm of effluent Ni in the system. It is concluded that the system represents a very efficient system for cleaning a metal polluted waste water.


The progress on this objective was hindered by the availability of the safety system for working with cyanide. This
hood system was not usable until early in 1989, so that only short term screening test could be performed. A number of isolates were screened for the capacity to utilize cyanide as a sole source of nitrogen for growth. None of the isolates were able to utilize cyanide. The long term enrichment system is the only likely system which will yield the desirable organisms. This process will require about 6 months to achieve, and will be reserved as a topic for a graduate project which we hope to start in September of 1989.

Publications & Professional Presentations


M.S. Theses:


Ph.D. Dissertations:

M-C. Lai, To be completed August, 1989.

Training accomplishments

Academic Level

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Figure 1. Diagram for application to clearing of metal plating waste water.
Figure 2. Effluent metal concentrations at various treatment time
Table 1. Metal Bioaccumulation by Arthrobacter SL-1

<table>
<thead>
<tr>
<th>Metal</th>
<th>Initial Conc.</th>
<th>Concentration 10 min</th>
<th>Concentration 130 min</th>
<th>Cell Dry Weight mg/ml</th>
<th>%Cellular Accumulation 10 min</th>
<th>%Cellular Accumulation 130 min</th>
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<tr>
<td>Pb</td>
<td>250 uM</td>
<td>1.9</td>
<td>5</td>
<td>22.6</td>
<td>99</td>
<td>98</td>
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<tr>
<td>Ag</td>
<td>470</td>
<td>53</td>
<td>133</td>
<td>22.6</td>
<td>89</td>
<td>72</td>
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<tr>
<td>Cd</td>
<td>150</td>
<td>17</td>
<td>8</td>
<td>23.9</td>
<td>89</td>
<td>95</td>
</tr>
<tr>
<td>Hg</td>
<td>250</td>
<td>47</td>
<td>105</td>
<td>23.9</td>
<td>81</td>
<td>58</td>
</tr>
<tr>
<td>Cr</td>
<td>960</td>
<td>960</td>
<td>498</td>
<td>24.6</td>
<td>0</td>
<td>48</td>
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<tr>
<td>Cu</td>
<td>800</td>
<td>48</td>
<td>38</td>
<td>24.6</td>
<td>40</td>
<td>53</td>
</tr>
<tr>
<td>Ni</td>
<td>850</td>
<td>286</td>
<td>48</td>
<td>24.6</td>
<td>66</td>
<td>94</td>
</tr>
<tr>
<td>Zn</td>
<td>770</td>
<td>177</td>
<td>29</td>
<td>24.6</td>
<td>77</td>
<td>96</td>
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Reaction Times, 10 and 130 minutes in Pipes buffer, 30°C

Figure 2. Effluent metal concentrations at various treatment time
SYNOPSIS

Project Number: 05  
Start: 6/1/88  
End: 5/31/89

Title: Evaluating Plants for Nutrient Retention in Vegetative Buffer Strips.

Investigators: Richard J. Hull, Plant Sciences Department, University of Rhode Island, Kingston, RI 02881

COWWR: 05B, 05G  
Congressional District: 2nd, R. I.

Key Words: Fertilizers, Groundwater management, Infiltration, Land use, Nitrogen, Nutrients, Plant growth, Rainfall-runoff processes, Riparian vegetation, Solute transport, Surface drainage, Water-quality management, Watershed management

Problem and Research Objectives:

Ground and surface water resources constitute the primary potable water supplies available to Rhode Island and the urban Northeast. Increasingly the quality of this is being threatened by the growing intensity of land use: agricultural, domestic and industrial. Strategies for protecting the quality of water resources have concentrated on protective zones surrounding surface reservoirs and local restrictions on development over major aquifers. These efforts are being compromised by the expansion of intensive land uses adjacent to tributaries and aquifer recharge areas. The resulting deterioration of water quality is a growing concern for managers of municipal water supplies, local governments, and land-use planners.

While land management practices are being developed which will reduce the leaching of pollutants into ground water, much less is known about the fate of materials which are washed off land surfaces by rain water. Vegetative buffer strips or zones have been used effectively to retard the overland movement of soil associated with surface runoff from agricultural and other intensive land use activities. These strips are designed primarily to retain particulate materials but their capacity to trap soluble mineral nutrients, heavy metals, and organic compounds is less well understood. The capacity of vegetative buffer strips to shield surface water bodies from soluble materials washed off adjacent land areas must be evaluated before their use for this purpose can be recommended.
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This research evaluates a broad range of plants for their capacity to absorb mineral nutrients and transport these elements to their shoots which can be harvested and removed from the site. The utilization of plants, which are found to be efficient in recovering nutrients from the soil, during the design and construction of buffer strips will increase the effectiveness of these structures to protect surface waters from pollution by both particulate and soluble materials.

**Methodology:**

a) Kinetic parameters for nutrient absorption by selected plant species were determined using a solution depletion technique. Seeds were germinated on 5 cm diameter disks of nylon screening mounted over holes in black plexiglass strips. When these strips were placed over plastic tubs filled with aerated nutrient solution the screens remained moist and the seeds germinated quickly with their roots extending into the nutrient solution.

After a vigorous root system had developed, the grass cultures were transferred from quarter-strength Hoagland's solution to a similar solution lacking nitrogen. They were maintained in this nitrogen-free solution for 24 hours at which time they were transferred to a nutrient solution containing 0.5 mM nitrate. We concentrated on nitrate because it is the nutrient of greatest concern as a ground and surface water pollutant. Total solution volume for each grass culture was about 350 ml when they were introduced to the 0.5 mM nitrate solution. One ml aliquots of solution were taken every 30 minutes until the nitrate concentration had been depleted to approximately 0.1 mM when the sampling frequency was increased to ten minute intervals. This was continued until the nitrate level was below a detectable concentration. Nitrate was analyzed by reducing it to nitrite on a Cd-Cu reduction column followed by a spectrophotometric nitrite determination.

Following an absorption experiment, the roots were excised, blotted free of water, and weighed. Based on the nitrate loss from the nutrient solution between each sampling time, nitrate absorption rates were calculated as μmoles NO3/ gram fresh root/hour. These were plotted against nitrate concentration and the absorption parameters computed based on the equation:

\[
V = V_{max} \cdot \frac{C_o}{K + C_o}
\]
where $V$ - the nitrate absorption rate.

$V_{\text{max}}$ - the maximum rate of nitrate absorption for the saturable phase of uptake.

$C_0$ - the nitrate concentration of the nutrient solution.

$k_0$ - the nitrate concentration which will support half of the $V_{\text{max}}$ rate of uptake. This is also the dissociation constant of nitrate from its transport protein.

$k$ - the first-order rate constant of the linear phase (nonsaturable) of nitrate uptake.

The linear uptake constant ($k$) was derived from the uptake rate by nitrate concentration curve over the range of 0.5 mM to 0.1 mM nitrate. The saturable uptake phase of nitrate absorption was determined over the range of 0 to 0.2 mM and the kinetic parameters $V_{\text{max}}$ and $k_0$ calculated from that.

Plants compared in this study included the commonly used grasses: tall fescue (*Festuca arundinacea* Schreb.) and reed canarygrass (*Phalaris arundinacea* L.). Also compared were the turfgrasses: perennial ryegrass (*Lolium perenne* L.) and Kentucky bluegrass (*Poa pratensis* L.); the forage grasses: smooth bromegrass (*Bromus inermis* Leyss.), orchardgrass (*Dactylis glomerata* L.) and timothy (*Phleum pratense* L.); and the prairie grasses: buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.) and blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.).

b. Nitrate leaching from the soil and nitrogen transport to shoots were studied for the same grasses under both greenhouse and field conditions. Ceramic lysimeter plates were installed below newly established stands of these grasses at a depth of 70 cm to intercept water that passed below the root zone. Nitrogen was applied at a rate of 177 kg/ha (160 lb/a) per year with applications made before planting on April 20, on August 22, and on September 30. Late in 1988 and following every significant rain following the spring thaw in March, lysimeter samples were collected and analyzed for nitrate.

A greenhouse study was initiated during the spring of 1988 in which the same grasses were seeded into column lysimeters. The lysimeters were constructed of PVC pipe and were 15 cm in diameter and 45 cm tall. Ceramic plates were mounted in the base of these lysimeters which permitted the recovery of all water leaching through the root zone. The greenhouse light, temperature and photoperiod were maintained so as to provide near optimum growing conditions for the grasses. Grass leaf growth
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**Principal Findings and Significance:**

The determination of nitrate uptake parameters did not prove to be as easy for these grasses as for other plant systems with which we have had experience. During the absorption period, uptake rates varied considerably making the calculation of a linear absorption constant difficult and unreliable. Changing greenhouse conditions as the season progressed and during a single uptake experiment accounted for some of this variability. Transferring the grass cultures to the laboratory and measuring nitrate depletion under a constant artificial light source (sodium vapor lamp) reduced the variability.

Rates of nitrate absorption were always low during the first 30 to 60 minutes of an uptake experiment. This was followed by high rates of absorption between 90 and 180 minutes which gradually declined as the solution nitrate concentration decreased. Because nitrate uptake and reduction in plant roots occurs through the action of inducible proteins (transporters and enzymes respectively) the 24 hours of nitrate-free culture preceding each absorption experiment may have produced roots deficient in these proteins. When the roots were again introduced to nitrate, the induced synthesis of nitrate transport and reduction proteins occurred but approximately one hour was required for this to support full uptake. When grass cultures were preconditioned in a nitrate containing solution, this initial low absorption rate was reduced but not eliminated.

To provide a sufficiently long uptake time so any initial variations in the absorption rate would not compromise the accurate estimation of the linear rate constant, the nitrate concentration used for these experiments was increased to 1.0 or 1.5 mM. These modifications of the experimental protocol have permitted the construction of a few good uptake kinetics curves. This research is continuing and we hope to have good results from all the grasses studied before the completion report is prepared.

The average nitrate concentration in the leachate from the grasses studied ranged from 0.88 to 31.59 mg NO₃-N/L. The low concentrations (less than 10.0 mg/L) were collected from the orchardgrass and tall fescue plots. Nitrate-N concentrations in excess of 10.0 mg/L were recovered from Kentucky bluegrass, perennial ryegrass and reed canarygrass plots. Soil
solution beneath bromegrass plots contained nitrate levels greater than 20 mg/L.

The movement of nitrates towards ground water, computed as loading in kilograms per hectare, ranged from 2.2 to 106.1 kg/ha during the time since fall 1988. Orchardgrass leached least and bromegrass most (2.0 vrs. 50.0 kg N/ha) during the sampling period. Mass loading and nitrate concentration exhibited a marked increase during the fall sampling period through early spring. By mid April, the nitrate concentration declined while the leachate volume remained constant. This corresponds to the time of spring green-up and growth of many cool season grasses. This trend was not apparent for bromegrass and reed canarygrass.

Nitrate leaching from the column lysimeters was difficult to interpret. Both the concentrations of nitrate and the leachate volume were low, with mass loading values rarely higher than 1.0 kg N/ha. Leaf tissue nitrogen concentrations were highest in perennial ryegrass, reed canarygrass, Kentucky bluegrass and bromegrass grown under the same relatively constant environmental conditions.

These data are too preliminary to draw any conclusions. Kinetic constants for nitrate absorption will be correlated with nitrate levels in soil water and ground water loading estimates from both field and greenhouse lysimeter studied. It appears that such relationships will vary during the year and vegetation must be selected or combined so as to maximize the duration of nitrate uptake and removal from the soil water in the root zone.

**Publications and Professional Presentations:**


Informal presentations have been made to representatives of the Soil Conservation Service and other interested parties.

**Thesis:**
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Informal presentations have been made to representatives of the Soil Conservation Service and other interested parties.

**Thesis:**

Two graduate students, J.L. Lemunyon and H. Liu are contributing to this project as part of their doctoral dissertation research.
SYNOPSIS

Project number: 06 Start: 6/1/88
End: 5/31/89

Title: MICROBIAL PROCESSES CONTROLLING THE FATE OF NITROGEN IN VEGETATIVE BUFFER STRIPS

Investigators: P. M. Groffman, W. M. Sullivan, J. L. Lemunyon
University of Rhode Island, Kingston, R.I.

COWRR Category: 05-B Congressional District: 2nd, R.I.

Keywords: Denitrification, Nitrogen, Pollution control

PROBLEM AND RESEARCH OBJECTIVES:

The movement of sediments and nutrients from terrestrial environments into water bodies is a critical threat to water quality in many areas (Karr and Schlosser 1978), including Narragansett Bay. Agricultural and suburban land uses and construction can deliver substantial loads of sediment and nutrients into water bodies, leading to eutrophication and sedimentation (Ryther and Dunstan 1971, Lowrance et al. 1984). Eutrophication and sedimentation reduce water quality for drinking supplies, navigation, fisheries and recreational uses.

An emerging technique for controlling movement of sediments, nutrients and other pollutants moving from terrestrial environments into water bodies is the use of vegetative buffer strips (VBS). Small strips of grass or other vegetation can be used to trap pollutants moving from land areas before they enter water bodies. The maintenance of riparian filter strips was adopted as a "best management practice" (BMP) by the USDA SCS (Dillaha et al. 1988) and are recommended for use as a complement to structural stormwater control devices in Rhode Island (Scott 1988). Despite the emerging widespread use of VBS, the scientific basis for their effectiveness is highly questionable (Hayes et al. 1988). There is a great need for research to determine if current buffer guidelines are too weak, too strong, or altogether inappropriate.

The concept of buffer strips originated from research that found that strips of riparian forest vegetation were important in maintaining stream water quality in areas of intensive agriculture (Karr and Schlosser 1978, Lowrance et al. 1984, Jacobs and Gilliam 1985). Research on optimal design and management for VBS began in the 1980's (Magette et al. 1987). Most studies have focused on removal of sediment in surface runoff by grass VBS (Young et al. 1980, Magette et al. 1987, Dillaha et al. 1988). Other studies have analyzed the role of natural forest and wetland
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Keywords: Denitrification, Nitrogen, Pollution control

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The movement of sediments and nutrients from terrestrial environments into water bodies is a critical threat to water quality in many areas (Karr and Schlosser 1978), including Narragansett Bay. Agricultural and suburban land uses and construction can deliver substantial loads of sediment and nutrients into water bodies, leading to eutrophication and sedimentation (Pyther and Dunstan 1971, Lowrance et al. 1984). Eutrophication and sedimentation reduce water quality for drinking supplies, navigation, fisheries and recreational uses.

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Despite the emerging widespread use of VBS, the scientific basis for their effectiveness is highly questionable (Hayes et al. 1988). There is a great need for research to determine if current buffer guidelines are too weak, too strong, or altogether inappropriate.

The concept of buffer strips originated from research that found that strips of riparian forest vegetation were important in maintaining stream water quality in areas of intensive agriculture (Karr and Schlosser 1978, Lowrance et al. 1984), then used for erosion control (Robbins and Gillian 1985). Research on optimal design and management for VBS began in the 1980's (Magette et al. 1987). Most studies have focused on removal of sediment in surface runoff by grass VBS (Young et al. 1980, Magette et al. 1987, Bilhara et al. 1988). Other studies have analyzed the role of natural forest and wetland vegetation as pollutant buffers (Brown et al. 1987, Broderick et al. 1988).

A major unresolved question relating to nutrient dynamics in VBS centers around nitrogen (N). Nitrogen is heavily applied to agricultural and suburban land uses, is highly mobile and is a prime cause of eutrophication and sedimentation in Rhode Island waterways (Lee and Olsen 1985). Several studies have addressed removal of N by VBS (Doyle et al. 1977, Thompson et al. 1978, Young et al. 1980) but results from these studies varied markedly and they did not address the specific microbial processes that regulate N dynamics in VBS. More importantly, these studies did not address the fate of N absorbed by VBS. Of particular concern is the fact that the main control mechanism of VBS is to increase infiltration of runoff which may merely transmit surface runoff pollutants to groundwater.

The key N cycle processes regulating N dynamics in VBS are plant uptake, immobilization, and denitrification. Immobilization is the uptake of mineral N by microorganisms and denitrification refers to the transformation of nitrate (NO₃⁻) into nitrogen gas. Denitrification is an anaerobic process, occurring primarily in saturated, poorly drained soils. The objectives of our study were to quantify N leaching, denitrification and immobilization of N in a variety of VBS in Rhode Island.

METHODOLOGY:

This experiment was conducted at the University of Rhode Island's Peckham Farm, in Kingston, Rhode Island. Experimental VBS were established as part on an ongoing USDA SCS study on soil classified as a Typic Dystrudept. This soil contained 0.92% organic carbon, 2.53% organic matter, and a pH of 5.89. The full scope of the buffer strip consisted of 10 different species of grasses, each replicated three times, making a total of 30 plots. Each plot measured 3 meters x 5 meters in size, with a 0.70 meter alleyway between alternate plots. Situated above the grass plots was a 25 meter x 100 meter oat field which was graded to a 2% slope to provide runoff onto the grass plots.

Ceramic lysimeter plates were installed below each VBS to collect water percolating below the root zone as part of the ongoing SCS study. The plates were installed in triplicate below each of the ten species at an average depth of 70 cm. Leachate samples were collected for selected events in late 1988 and have been collected for every percolation event since March 10, 1989 as part of the SCS study. Nitrate in leachate samples was quantified using on chromatograph. On April 20, 1988, the grass plots, along with the oat field, were treated with 33 kg/ha of N, in the form of urea. Additional treatments with urea were confined to the grass plots. On July 22, 1988, 96 kg
N/ha was added as a top dressing, and on September 30, 1988 another 48 kg N/ha was added to boost root and rhizome production for the winter. The plots were sprayed on June 8, 1988 with 0.28 kg/ha of Buctril and .07 kg/ha of Banvel, both of which are for broadleaved weed control. Additional spot treatment for *Agropyron repens*, was accomplished using a 2% glyphosate solution. The plots were mowed four times to a height of three inches to suppress weeds, allow the grasses to fill the plots, and to prevent the grasses from going to seed.

For microbial process studies, only two of the grass treatments, common reed canary grass (*Phalaris arundinacea*) and tribute tall fescue (*Festuca arundinacea*) were used. The reed canary grass was chosen because it is well adapted to a moist environment (such as riparian areas) and has the ability to uptake large quantities of nutrients. The tall fescue was chosen because it is a common plant used in many other studies. We also located microbial process study plots in well and poorly drained riparian forest sites adjacent to the grass VBS study area. The poorly drained site was situated in a soil that was classified as an Aquic Dystrochrept, with a depth to mottles of 25 cm. This soil contained 8.5% organic carbon, 0.32% total N, and a pH of 3.52. In the well drained site, the soil was classified as a Typic Dystrochrept, with a 66 cm. depth to mottles. This soil contained 5.1% organic carbon, 0.25% total N, and a pH of 4.23. Sub-plots of the forest sites were treated with lime (20 lbs/ft² in the poorly drained, 10 lbs/ft² in the well drained) to test for pH limitation of microbial N processes.

Denitrification was measured using soil core techniques described by Groffman and Tiedje (1989). Cores of 15 cm depth and 2 cm diameter were removed from soil, placed in plexiglass tubes and sealed with rubber serum stoppers. Cores were subjected to a variety of amendments. Acetylene was added to inhibit the final step in the denitrification process, allowing us to quantify denitrification rates by measuring the accumulation of nitrous oxide (N₂O) in the sealed cores (Yoshinari and Knowles 1976). Nitrate was added to some cores to simulate runoff events and glucose was added to some cores to test for carbon limitation of denitrification. Denitrification measurements were made over two three day periods in July, over a 9 day period in August and at two dates in September of 1988. Immobilization of N was measured by treating soils in the laboratory with simulated runoff and measuring levels of inorganic N in soil over an 8 day period.
N/ha was added as a top dressing, and on September 30, 1988 another 48 kg N/ha was added to boost root and rhizome production for the winter. The plots were sprayed on June 8, 1988 with 0.28 kg/ha of Buctril and 0.07 kg/ha of Banvel, both of which are for broadleaved weed control. Additional spot treatment for Agropyron repens, was accomplished using a 25 glyphosate solution. The plots were mowed four times to a height of three inches to suppress weeds, allow the grasses to fill the plots, and to prevent the grasses from going to seed.

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Denitrification was measured using soil core techniques described by Groffman and Tiedje (1989). Cores of 15 cm diameter and 2 cm diameter were removed from soil, placed in plexiglass tubes and sealed with rubber serum stoppers. Cores were subjected to a variety of amendments. Acetilene was added to some cores to simulate runoff events and glucose was added to some cores to test for carbon limitation of denitrification. Denitrification measurements were made over two three day periods in July, over a 9 day period in August, and at two dates in September of 1988.

Immobilization of N was measured by treating soils in the laboratory with simulated runoff and measuring levels of inorganic N in soil over a 8 day period.

PRINCIPAL FINDINGS AND SIGNIFICANCE:

The average concentrations of NO^- in leachate from the 10 grass species ranged from 0.9 to 31.6 mg/L. Loading rates of NO^- to groundwater ranged from 2.2 to 106.1 kg/ha. The 10 grasses can be broken into four groups based on their loading rates:

<table>
<thead>
<tr>
<th>Loading Rate (kg/ha)</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0 to 10.0</td>
<td>orchardgrass, sweet vernalgrass</td>
</tr>
<tr>
<td>10.0 to 25.0</td>
<td>tall fescue, creeping foxtail</td>
</tr>
<tr>
<td>25.0 to 50.0</td>
<td>perennial ryegrass, Big Bluestem</td>
</tr>
<tr>
<td>50.0 to 106.1</td>
<td>Kentucky bluegrass, reed canary</td>
</tr>
</tbody>
</table>

These results suggest that the different grasses have dramatically different abilities to take up N. It is important to note that all grasses received 177 kg N/ha as fertilizer and therefore all grasses demonstrated a significant ability to take up N. In buffers receiving lower inputs of N from runoff, differences in uptake and leaching may be less dramatic. It is also important to note that the ability of grasses to take up N fertilizer does not necessarily predict their ability to remove N from runoff. We had hoped to directly measure removal of N from runoff during the summer of 1988, but technical difficulties hindered our efforts. These experiments will be done during 1989.

Unamended rates of denitrification were very low (< 10 kg N/ha at 10 days) and were highest in the poorly drained forest plot. This was as expected since soil moisture was highest in this plot. The grass plots had a much higher ability to denitrify NO^- in simulated runoff than the forest plots. In a three day experiment in July, rates of denitrification in the tall fescue and reed canary grass soils were 7889 and 4537 g N ha^-1 d^-1 respectively, while in the well drained and poorly drained forest plots averaged 111 and 365 g N ha^-1 d^-1 respectively. A similar pattern was observed in an 11 day experiment in August. These results suggest that denitrification can significantly reduce levels of NO^- added to VBS, but should be interpreted with caution since they are from laboratory experiments. Measurement of denitrification during in-field runoff events was scheduled for the summer of 1989, but will not be done until the summer of 1989. Addition of glucose significantly increased rates of denitrification in NO^- amended cores, suggesting that the availability of carbon sources may ultimately limit the capacity of VBS to remove NO^- through denitrification.

We expected the forest plots to have a much higher potential for denitrification than the grass plots, since forest soils generally have higher moisture and organic matter levels than upland agricultural soils. To test the hypothesis that low pH in the forest soils reduced denitrification in these soils relative to the grass plots,
we added lime to the forest plots. Although we successfully raised the pH in the forest plots from 3.5 to 4.8 in the poorly drained plot and from 4.2 to 4.9 in the well drained plot (pH in the grass plots was 5.3), denitrification rates did not increase accordingly. Denitrification was actually significantly lower in the limed plots than in the unlimed plots in most cases. This is likely due to the fact that microbes in soil are adapted to in situ physical and chemical conditions and changing the pH thus reduced their activity (Koskinen and Keeney 1982). In the long term, raising soil pH should lead to the development of a different microbial community, with higher denitrification activity (Parkin et al. 1985). These results suggest that riparian zones in Rhode Island may not always be effective denitrification sinks for NO₃⁻, and that managing these zones to increase denitrification is not simple and requires long-term study.

We measured immobilization by monitoring mineral N levels in soils for eight days following addition of a 4 ppm slug of NO₃⁻. All soils other than the poorly drained forest were able to immediately absorb the added NO₃⁻. However, levels of mineral N increased in all soils over the eight day incubation. These results suggest that immobilization is only a temporary sink for NO₃⁻, and that any N that is immobilized may be subsequently released (mineralized). Mineralization was highest in the poorly drained forest soil and was higher in the reed’s canary grass than in the tall fescue soil.

In summary, we demonstrated that there are major differences in the nature and extent of microbial processes in VBS of different types of grasses and soils. Our results suggest that low pH may limit the ability of forest soils to act as buffers, and that availability of carbon sources may ultimately limit denitrification in VBS. The study also suggests that N that is immobilized in VBS may be subject to re-mineralization and release. Management of VBS should focus on maximizing N removal by denitrification and/or plant harvest.

PUBLICATIONS AND PROFESSIONAL PRESENTATIONS:


M.S. NON-THESIS MAJOR PROJECT:

Eric A. Axelrod. Denitrification in vegetated buffer strips.
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PUBLICATIONS AND PROFESSIONAL PRESENTATIONS:


N.S. NON-THESIS MAJOR PROJECT:

Eric A. Axelrod. Denitrification in vegetated buffer strips.

LITERATURE CITED:


SYNOPSIS

Project Number: SI
Start: 11/87
End: 05/89

Title: Study of Fly Ash & Bottom Ash & Their Leachate Characteristics in a Simulated Landfill Condition

Investigators: Calvin P.C. Poon, University of Rhode Island

COWRR: 05A, 05B
Congressional District: Second

Keywords: Acid Rain, Contaminant Transport, Evapotranspiration, Hazardous Waste, Infiltration, Leaching, Sanitary Landfills

Problem and Research Objective:

The state of Rhode Island is going to build three solid waste incinerators in the near future. Incinerator operations in other states show that the ash is a potentially hazardous waste material. In light of the unique design using high-alkaline flue gas scrubber and the new USEPA extraction protocol (TCLP) in defining hazardous waste, it is necessary to study the characteristics of the ash using both the existing EPTC protocol and the proposed TCLP protocol. Special attention will be given to heavy metals cadmium (Cd) and lead (Pb) as they are most commonly found in incinerator ash. With the acid rainfall in the northeast region, it is a major concern if the leachate from a landfill for ash disposal would contain Cd and Pb. Therefore, simulated landfill studies using columns in laboratory will be useful to characterize the leachate quantity as well as quality. The result will be useful for future design of landfill used for ash disposal.

Methodology:

Columns containing a sand layer in the bottom with drains and ash or ash/municipal solid waste layers were used to simulate landfills. Artificial acid rains were introduced to the columns based on a typical Rhode Island rainfall condition. Leachate samples were collected for chemical analysis. Interactions of Cd and Pb with other substances in the simulated landfills were examined. A computer HELP model was used for the study. Experimental data were obtained to calibrate the model after which it was used to estimate the infiltration and leachate drainage rates of landfills of different designs.

Principal Findings and Significance:

Using the existing EPTC extraction procedure, the incinerator ash/residue was not
if the newly proposed TCLP procedure by USEPA was used. Either procedure showed that the ash/residue was a hazardous substance in reference to Pb. Deionized water extraction at pH 4.95 showed that the ash/residue was nonhazardous for both Cd and Pb.

The simulated landfill or column study showed that initially the landfill under saturated conditions would produce leachate containing 4.9 ppm Pb and 15-16 ppb Cd. The concentration of both metal decreased rapidly under the typical rainfall condition in Rhode Island with Pb at 5.6 ppb and Cd at 0.31 ppb after 250 days and remained at or below these low levels thereafter.

Organic acids in the leachate, mainly formic and acetic acids, facilitated Pb and Cd mobilization. However, by using the Sep-Pak separation procedure, it was shown that most of the Cd and Pb found in the leachate was in the free ionic form, despite the presence of these organic acids. The simulated landfill also converted sulfate into sulfide which helped to immobilize Cd and Pb. In a long term it was expected that more sulfide would accumulate in the landfill due to the anoxic condition, further immobilize Cd and Pb. resulting in even lower Pb and Cd concentrations in the leachate.

Under the typical rainfall conditions in Rhode Island, it was found that out of the annual 44 inches of precipitation, 5.1 inches would evaporate and 36.4 inches of leachate could be collected from drains. The HELP Model was found to be a very useful tool for the estimation of evaporation, evapotranspiration, infiltration, and leachate drainage. The results are currently being used in preliminary engineering design of ash landfill and in the development of a study of leachate treatability for the Rhode Island Solid Waste Management Corp.

Thesis:

A Ph.D. dissertation is underway.
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Thesis:
A Ph.D. dissertation is underway.

SYNOPSIS

Project Number: S2
Start 12/88
End 12/89

Title: Simultaneous Removal of Cyanide & Heavy Metals from Industrial Process Wastewaters
Investigators: Poon, Calvin P.C., University of Rhode Island
COWRR: 05D
Congressional District: Second
Keywords: Heavy Metals, Industrial Wastewater, Wastewater Treatment

Problem and Research Objectives:

The industrial pretreatment program of the Narragansett Bay Commission has identified total metal loadings to their Field Point Wastewater Treatment Facility to be 363,645 pounds and total cyanide loadings to be 27,043 pounds in 1987. The industrial contribution of these metals was calculated to be between 60 to 90% of the total metal load to the treatment facility but only 7% of the total flow. The three largest loadings of metals were zinc, copper, and nickel which together made up more than 90% of the total metal loadings. Within the Narragansett Bay Commission district, there are 121 electroplaters and metal finishers as well as 129 companies identified as possibly having casting operations, all contributing in part to the total metal and cyanide loadings.

The objectives of the research have been to demonstrate the feasibility of a physical-chemical treatment process, using a brine solution electrolysis, in simultaneous removal of cyanide, nickel, copper, and zinc.

Methodology:

A compact reactor was built with platinated columbium anode and stainless steel cathode. The space between the horizontally laid anode screen and cathode screen was filled with a rock salt solution as the anolyte. The wastewater containing heavy metal and cyanide was introduced on top of the rock salt solution layer. The electrolysis of the rock salt solution generated chlorine to destroy cyanide and hydroxides to precipitate the heavy metal. Gas bubbles carried the precipitated metal to the top to form a scum layer. The scum layer was collected acid dissolved, to form a high concentrated metal solution from which the metal could be plated out.

Principal Findings and significance:

By applying a direct current from 3 to 6 volts and a current density of about 3.6
to 6 mA/cm², preliminary experimental results indicated successful removal of copper, nickel, and cyanide to levels meeting the pretreatment standards. Effluents of 0.5 ppm Cu, 0.3 ppm Ni and 0.5 ppm CN could be achieved easily in either batch or continuous flow process. The treatment experiments with a Latin Square statistical design will be carried into the FY-89 program. Also the metal plating-out process from the acidified scum solution will be tried in the FY-89 program.
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INFORMATION TRANSFER ACTIVITIES

Project No.: 22 Information Transfer Activities

Title: Environmental Education: Water Protection, Management, and Conservation

Investigators: William R. Wright, Ph.D.
Department of Natural Resource Science, URI
Calvin P. C. Poon, Ph.D.
Department of Civil and Environmental Engineering, URI
Arthur J. Gold, Ph.D.
Department of Natural Resources Science, URI
Thomas P. Husband, Ph.D.
Department of Natural Resources Science, URI

COWWR: 10C, D Congressional District: 2nd, RI

Key Words: Groundwater Quality (76), Land Use (101), Septic Tanks (163), Water Quality Monitoring (206)

Problem and Research Objectives:

Two major sources of drinking water, surface and groundwater, exist in Rhode Island. The Scituate Reservoir serves approximately 60 percent of the state, with a safe yield capacity of 78 million gallons per day (MGD). The southern part of the state is dependent on a large aquifer network. On December 1, 1987, a petition for Environmental Protection Agency designation for the Pawcatuck Basin Aquifer as a Sole Source Aquifer was submitted. The concern lies in the pressures of increased water demand and water degradation caused by accelerated urban development. Research conducted by the Rhode Island Department of Environmental Management (DEM) presented in The Groundwater Protection Strategy cites a growing number of contaminated drinking water wells throughout the state. Such nonpoint sources as agricultural and urban runoff add to pollution loading. Protection of these sole-source water supplies is critical to meet future demands for potable water. Important forces in accomplishing this protection are informed decision makers and an educated public. A comprehensive Technology Transfer Program can target key groups and disseminate information on planning strategies for effective land use and water protection.

Methodology:

To ensure that water resource management occurs in a way which both maintains areas of high water quality and improves degraded areas, people entrusted with executing planning decisions must have technical information accessible. The University of Rhode Island can implement programs of technology transfer.

As a strong research base committed to water resource issues, the University can generate technical information. The University can integrate and support existing related water quality programs at state and local levels. The University also can increase scientific information on surface water quality in Rhode Island by compiling
background water quality data against which present conditions can be measured and evaluated. This Technology Transfer Program proposes to continue and to broaden the following programs initiated in FY 1987:

1. Printing of written materials, aimed at municipal decision makers and the general public on such topics as storm water management, fertilizers, buffer zones, and surface and groundwater quality;
2. Sponsoring of workshops on groundwater issues particularly addressing state and local strategies for groundwater protection;
3. Monitoring program for Watershed Watch, a citizen-based monitoring program for surface waters within the Pawcatuck Watershed, to be expanded to include the northern part of Rhode Island.

There are many benefits to the above programs. Better informed planning officials, as well as the general public, lead to land use decisions which ensure potable water supplies for the state. Working with environmental groups and state agencies, the University can offer technical assistance and strengthen existing water quality programs. A good example of this is the cooperative surface water monitoring program, Watershed Watch, which increases DEM's surface water quality data-base. On the local level, university assistance can serve to galvanize the public on key water quality issues.

Principal Activities and Significance:

A. **Watershed Watch**, a citizen-based monitoring program for surface waters with the Pawcatuck Watershed, was expanded to include the northern part of the state. Training materials were developed as part of a four-session training workshop in lake and river management which was held at the University of Rhode Island from June 1-22, 1989. The training consisted of three classroom sessions and one Saturday morning field exercise. Topics addressed at the workshop included:

1. Physical, chemical, and biological characteristics of RI surface waters.
2. Factors affecting surface water quality, including pollution sources, natural characteristics, and man-made alterations.
3. Conducting shoreline surveys to develop an inventory of natural characteristics and pollution sources.
4. Steps that individuals and organizations can take to protect water quality.

The emphasis of the training workshops was citizen involvement to help protect and manage surface water quality. More than 25 volunteers participated in the training. Each individual agreed to perform 20 hours annually in completing shoreline surveys or other management projects on a lake or river segment, working under the direction of a watershed coordinator and Watershed Watch staff.

B. **Conference on Groundwater Protection Strategies for Rhode Island.** It is estimated that 24% of Rhode Island's population depends on groundwater resources for their drinking water supply. Municipalities are responsible for protecting and ensuring the quality of their groundwater supplies. A one-day workshop was designed to address the needs and concerns of Rhode Island's communities for groundwater protection. The workshop was held on November 29, 1989 at the Whispering Pines Conference Center on the W. Alton Jones Campus in West Greenwich, RI. One hundred people attended the
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A. Watershed Watch, a citizen-based monitoring program for surface waters with the Pawcatuck Watershed, was expanded to include the northern part of the state. Training materials were developed as part of a four-session training workshop in lake and river management which was held at the University of Rhode Island from June 1-22, 1989. The training consisted of three classroom sessions and one Saturday morning field exercise. Topics addressed at the workshop included:

1. Physical, chemical, and biological characteristics of RI surface waters.
2. Factors affecting surface water quality, including pollution sources, natural characteristics, and man-made alterations.
3. Conducting shoreline surveys to develop an inventory of natural characteristics and pollution sources.
4. Steps that individuals and organizations can take to protect water quality.

The emphasis of the training workshops was citizen involvement to help protect and manage surface water quality. More than 25 volunteers participated in the training. Each individual agreed to perform 20 hours annually in completing shoreline surveys or other management projects on a lake or river segment, working under the direction of a watershed coordinator and Watershed Watch staff.

B. Conference on Groundwater Protection Strategies for Rhode Island. It is estimated that 24% of Rhode Island's population depends on groundwater resources for their drinking water supply. Municipalities are responsible for protecting and ensuring the quality of their groundwater supplies. A one-day workshop was designed to address the needs and concerns of Rhode Island's communities for groundwater protection. The workshop was held on November 29, 1989 at the Whispering Pines Conference Center on the W. Alton Jones Campus in West Greenwich, RI. One hundred people attended the conference, included representatives of local, state, federal governments and private organizations. Local and regional experts presented tools for developing local groundwater protection programs.

A resource room was set up and open throughout the day in which eleven different groups and organizations involved in groundwater protection issues displayed informational materials and answered questions. Those involved in the resource room included:

1. The Department of Natural Resources Science, URI
2. RI Environmental Data Center
3. RI Department of Environmental Management
4. US EPA, Region 1 Office
5. Resource Conservation and Development
6. USDA Soil Conservation Service
7. Narragansett Bay Project
8. Rural New England
9. New England Interstate Water Pollution Control Commission
10. Connecticut Department of Environmental Protection
11. US Geologic Survey

Participants received a resource notebook in addition to handouts and informational materials displayed at the resource tables. Attached are copies of the conference brochure and program.

The objectives of the conference were to: 1. present groundwater protection strategies to local decision makers, 2. increase local officials' knowledge of RI's groundwater hydrology, 3. update local officials on regulation and laws pertaining to groundwater protection, and 4. facilitate networking between groundwater professional and local decision makers. The conference accomplished all of its stated objectives.

Newsletter, published on September 1, and December 1, 1987, and on March 1, and June 1, 1988 by this Center were distributed to the public as well as water agencies and the research community in Rhode Island, and all other 54 Water Resources research Institutes. Items covered in the newsletter included research project accomplishments, ongoing research works, the planning activities of this Center, announcements of other water resources related activities, as well as discussions on water related environmental issues relevant to the State of Rhode Island such as radon, sole source aquifer designation, hazardous waste handling in Rhode Island, on-site wastewater management districts, impact of environmental laws on real estate transactions, watershed watch and citizen participation.
COOPERATIVE ARRANGEMENTS

The Center has two advisory committees, the State Advisory Committee and the University Water Resource Coordinating Committee. By recommendation from the federal inspection team in FY-1986, both committee memberships have been expanded.

State Advisory Committee

Peter P. Calise, Manager, R. I. Water Resources Board
Rodney Driver, State Legislator
James W. Fester, Assistant Director of Regulation, R. I. Dept. of Environmental Management
Ellen Greiner, R. I. League of Women Voters
Herbert E. Johnston, Subdistrict Chief, U. S. Geological Survey
Vincent Rose, Chairman of Board, Save the Bay
Daniel W. Varin, Chief, Div. of Planning, R. I. Dept. of Administration
Mr. Alfred L. Hawkes, Director of the Audubon Society of R. I.

University Water Resources Coordinating Committee

Pei Wen Chang, Animal Pathology
Frank DeLuise, Mechanical Engineering
Reinhard K. Frohlich, Geology
Scott W. Nixon, Oceanography & Sea Grant Coordinator
James Opaluch, Resource Economics
Calvin P. C. Poon, Environmental Engineering
Leonard Worthen, Pharmacognosy

As in the past year, both committees have contributed significantly to the development and direction of the Center's program.

Project 02 worked closely with the R. I. Dept. of Health and the GIS system of the R. I. Dept. of Environmental Management at the University of Rhode Island for data processing and mapping.

Project 03 received guidance and information from the District Office of the U. S. Geological Survey, in Providence, in developing the project work. With some explored geological data available, the result of this project could be used to predict the time required for cleaning a contaminated aquifer by natural flushing in Rhode Island or elsewhere.

Project 05 and 06 worked closely with U. S. Dept. of Agriculture, soil Conservation Service on project design.
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Project 04 and S2 received assistance from the jewelry industry in Rhode Island. In addition, Project S2 worked closely with the Division of Environmental Coordination of the RIDEM, and the Association of Jewelry and Silversmiths of Rhode Island to develop the project objective.

Project S1 worked closely with and received technical assistance from the Rhode Island Solidwaste Management Corp. throughout the project.


The Center also participated in the second year program of the National Network for Water Policy Research and Analysis of the USEPA Office of Water by coordinating the effort of matching topics with student candidates from departments of various disciplines at the University of Rhode Island.
## TRAINING ACCOMPLISHMENT

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