FISCAL YEAR 1995
PROGRAM REPORT
FISCAL YEAR 1995 PROGRAM REPORT
Grant No. 14-08-0001-2044

for

U.S. Department of the Interior
Geological Survey

by

Water Resources Center
University of Rhode Island
Kingston, RI 02881

Calvin P. C. Poon, Director
July 1996

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The contents of this publication do not necessarily reflect the views and policies of the Department of the Interior, nor does mention of trade names or commercial products constitute their endorsement by the United States Government.
ABSTRACT

The objectives of the Rhode Island Water Resources Institute program for the recent years has been (1) to identify critical policy and management issues of water resources in the State and in the New England region, (2) to conduct research in order to generate information useful to address the issues and to solve the problems, (3) to transfer the information to potential users throughout the State and New England region, (4) to educate the public about water quality protection, and (5) to train both graduate and undergraduate students in water resources research. Current and anticipated state and regional water problems are aquifer protection in relation to turf farming management, increased cost of drinking water supply resulting from Safe Drinking Water Act Requirements in water quality monitoring, water quality aspects of wetland, radon removal from drinking water, the fate of phosphorus in riparian wetland forest, hazardous material removal/recovery as part of the pollution prevention program as well as contaminated site remediation, and information dissemination on geophysical techniques and economics in groundwater survey.

The FY-1995 program address many of these issues and problems. Eutrophication of freshwater bodies due to elevated phosphorus inputs is of increasing concern within Rhode Island. Riparian forested buffers are regarded as sinks of nonpoint source pollution and essential to protecting water quality in freshwater bodies. The potential for phosphorus removal was investigated using the equilibrium P concentration at zero sorption (EPC0). Soil properties and EPC0 were determined for 3 draining classes in a riparian forest. Mean EPC0 and soil property values were different between drainage classes. EPC0 means were different in May and November. For somewhat poorly drained soils, the forest appeared to become a source of P in the fall. The potential for P removal diminished rapidly as Fe, Al concentrations fell below a critical level. For remediation of petroleum contaminated sites, landfarming is an effective technology for soil decontamination. The process can be accomplished in a period of several weeks to several months. The soil at the site may have to be amended with nutrients supplement, pH and moisture control, and addition of surfacetant. Some detergent may not be effective because of the disinfection property. BioSolve appears to be better than other detergents studied in enhancing the bioremediation process. It is important that managers of turf and those responsible for protecting ground water resources understand the best cultural practices for minimizing nutrient release from turf areas. Soil mineralization of organic nitrogen in the fertilizer probably contribute to elevated soil water nitrate levels. Even the unfertilized plots contain soil water nitrate-nitrogen in excess of 1.0 mg nitrate-N/l (ppm) during late summer and fall. During the spring, nitrate-N levels are consistently less than 1.5 ppm. The higher urea-N treatment is evident by the elevated soil water nitrate levels. The 1.0 lb urea-N/1000 sq-ft application in mid-June results in a Nitrate-N concentration in soil water of 16 ppm the following July. Silver removal/recovery is important to the photo/X-ray processing industries for regulation compliance and for resources recovery reasons. At high silver concentrations, electrodeposition can be cost effective. At low concentrations, ion exchange process has to be used. A method of sulfuric acid treatment of the resin can prolong the useful life of the resin by going through the exchange/acid fixation cycles repeatedly. The exchange capacity of the resin IRA-68 can be increased 40 times or more. The effluent, at about 20 mg/l Ag, has to be diluted with tap water for further ion exchange treatment to reduce the Ag to 0.029 mg/l breakthrough concentration. Pollution
minimization and pollution prevention is necessary for the marine trade related industries including boat builders using fiber reinforced plastics and marinas to remain competitive and profitable. Hazardous waste management using solvent substitution, solvent reclamation, process substitution, material substitution, waste collection and recycling etc are found to be practical and cost saving in the production and yet maintaining the quality of the products or service.
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WATER PROBLEMS AND ISSUES OF RHODE ISLAND

Eutrophication of fresh water bodies due to elevated phosphorus (P) inputs is of increasing concern within the state of Rhode Island. Ten of the 42 lakes monitored in Rhode Island rank as eutrophic based on median chlorophyll trophic state index values. The increased primary productivity associated with eutrophication affects water quality by increasing concentrations of dissolved and particulate organic carbon, which constitute the main precursors of trihalomethanes (THMs) in surface waters. The USEPA has proposed new regulations that would lower the THM limit to 0.08 mg/l beginning in 1996. A lower THM standard will pose a difficult challenge to public water utilities that depend on eutrophic surface water supplies in Rhode Island. Controlling the sources of DOC in natural waters may prove to be an effective alternative to costly in-plant treatment for DOC removal. Controlling the non-point source P pollution of surface limits the primary production of algae and aquatic macrophytes which in turn limits the production of THMs. Riparian wetland areas, because of their flatter slopes and high surface roughness, tend to accumulate sediment-bound P in the runoff. Since wetland acts as either sources or sinks of P depending on hydrologic characteristics, there is a need to evaluate the role of the special landscape features of wetland as sources or sinks of P.

Rhode Island has many sites contaminated with hazardous materials. Almost without exception, the sites have contaminated soils as well as contaminated groundwater. Without decontamination the site cannot be used and the migration of the contaminants will not stop. More contaminants will reach the aquifer resulting in a greater negative impact on the environment. Some simple and cost-effective remediation method that can decontaminate the site for reuse is needed. Land farming can remove or destroy the contaminants in a short period of time. The process should be studied both in the laboratory and field scale and its applicability in Rhode Island can be evaluated.

Land development in southern New England is of such intensity that most areas are or soon will be subjected to some level of use. Shallow aquifers, especially those representing sole-source water supplies, need special protection but the land overlying them is often highly valued for residential or commercial development. While turf may constitute an environmentally sound ground cover over high value aquifer systems, it is important that managers of turf and those responsible for protecting ground water resources understand the best cultural practices for minimizing nutrient release from turf areas. Such knowledge will maximize the protective functions of turf and permit policy makers to assure the public that effective safeguards for the preservation of water quality are being implemented. Most research has concentrated on quantifying the discharge of pollutants into ground water. A study of fertilizer management strategies for turf culture which are most protective of ground water quality is needed.

There is a large number of firms in Rhode Island that discharge silver bearing wastewater. In the Narragansett Bay Commission (NBC) district alone, there are 122 firms of printing and photo or x-ray processing, 16 metal plating, and 1 firm in glass manufacturing discharging silver bearing waste into the NBC sewer system. The US EPA has designated 5 mg/l or more of silver as
"hazardous". Many sewer authorities simply adopt 5 mg/l as the discharge limit. However many sewer authorities lower the limit by taking into the consideration of the effect of silver toxicity in the receiving water as well as in the sewage treatment process and sludge quality. The current pretreatment standards for NBC system is 0.43 mg/l Ag maximum daily and 0.24 mg/l on a 10-day average. There is a proposal to lower the standards to a uniform concentration of 0.029 mg/l. Even the combined technology of metal exchange/electrolytic recovery recognized NY US EPA as the Best Demonstrated Applied Technology (BDAT) with a 99% silver recovery cannot produce an effluent with 0.029 mg/l of silver. There is a need to study the ion exchange technology for more efficient silver recovery and at the same time reducing the silver to the proposed level of 0.029 mg/l.

There are numerous boat builders in Rhode Island that use fiber reinforced plastics (FRP). Hazardous wastes and volatile organic compounds (VOCs) are generated in the boat building processes. To reduce the generation of hazardous wastes and VOCs while at the same time maintaining quality control, it is necessary to study various ways such as alternative solvent use, solvent reclamation, process substitution, and material management. The study is part of the effort of state pollution prevention program that is designed to minimize pollution and helps the state industries in their sustainable development.
PROGRAM GOALS AND PRIORITIES

With minor changes from last year’s program goal and research priorities, the State Advisory Committee and the University Water Resources Coordinating Committee set the following priorities:

Water Management

1. Evaluation of local and state land use and zoning regulations as well as wellhead protection Program on their impacts on water quality protection.

2. Management of wetlands as pollution mitigators.

3. Water conservation practices and effects.


Water Quality

1. Mitigating non-point sources of nutrients from runoffs.

2. Resources recovery and management from industries to meet discharge limits in Rhode Island.

3. Role of wetlands in pollutant removal.

Groundwater and Surface Water-Ground Water Interaction

1. Assessment of groundwater reservoir capacity and pollution in glacial deposit and bedrock Fractures.

2. Geophysical technology and economics in groundwater survey.

Technology Transfer

Education, preventive maintenance, and evaluation of risks of homeowner practices on individual wells and water quality in relation to the Rhode Island designated wellhead protection area, or information transfer of any of the research topics mentioned above.
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Project Summary

Project Number: 2
Start Date: 6-1-1995
End Date: 5-31-1996

Title: RIPARIAN FOREST SOILS AS SINKS AND SOURCES OF PHOSPHORUS: SPATIAL DISTRIBUTION PATTERNS AND MODELING

Investigators: Josef H. Görrès
José A Amador
Natural Resources Science Department
University of Rhode Island
Kingston, RI 02881

Focus Category: WL, NU
Congressional District: 2nd RI

Descriptors: Water Quality Riparian Land Phosphorus Removal Soil Chemistry Nonpoint Pollution Sources Soil Absorption Capacity

Rationale and Research Objectives:

Eutrophication of freshwater bodies due to elevated phosphorus inputs is of increasing concern within Rhode Island. Much of the State relies on surface water reservoirs for drinking water and the increased primary productivity results in high organic carbon concentrations which constitute precursors of trihalomethanes (THMs). THMs are potential human carcinogens and their presence in drinking water poses a public health threat.

Riparian forested buffers are regarded as sinks of nonpoint source pollution and essential to protecting water quality in freshwater bodies. In riparian ecosystems plant uptake, microbial assimilation, adsorption and the mechanical removal of sediments from overland flow, participate in the removal of phosphorus originating from agricultural or residential land uses. However, it is also possible that under certain conditions buffer strips may act as sources of phosphorus.
While it is recognized that riparian buffers have large potentials for removing nutrients and protecting water quality, mechanistic nonpoint source loading models treat riparian areas as neutral. There are a number of difficulties that need to be overcome before mechanistic components of phosphorus removal and release in riparian forests can be incorporated into nonpoint source loading models. The first is to identify processes which would explain both removal or release. The second is to measure parameters which describe these processes sufficiently accurately so that an assessment of the removal or release potential of a riparian forest buffer can be undertaken.

The removal or release of phosphorus will most likely occur in the forest floor and the upper most mineral layer. The focus of this project was on soluble phosphorus, so that a measure of adsorption and desorption of phosphorus in soils was a critical component for this project. The variability of soils was considered one of the problems in the estimation of areal means of source or sink parameters.

Our objectives were to
- provide a measure of phosphorus adsorption and desorption
- determine whether a particular drainage class was particularly effective in phosphorus removal
- determine whether spatial dependence needed to be considered in the measurement of adsorption or desorption
- determine whether adsorption and desorption were temporally variable.

Our hypotheses were that
- the potential for phosphorus removal or release varies with Fe and Al ions, and organic matter
- adsorption or desorption differs in different drainage zones
- adsorption and desorption are spatially and temporally variable.

Methodology

A riparian forest located down gradient from an agricultural area was chosen to conduct the research. The forest is on glacial outwash and contains a soil drainage catena. The soil at the site is a Hinkley sandy loam with an average surface slope of 3%. The upland forest is dominated by oak (Quercus spp.), grading into a red maple (Acer rubrum) swamp.

A plot was established which was 25 m long and 15 m wide. The plot was oriented such that the long side was normal to the gradient. The plot was placed to span three consecutive drainage classes: moderately well, somewhat poorly and poorly drained. The drainage classes were delineated within the plot using soil morphological features. Each
drainage class had a width of approximately 5 m. 100 samples were taken in each drainage class in May 1995 and November 1995, giving a total of 300 samples per sampling date. To satisfy geostatistical sampling criteria, the sampling scheme was a nested stratified random design. This design created distances between points that varied from very short (about 5 m) to very long (about 25 m) within each drainage class. For the first sampling all points were surveyed to a common origin to allow geostatistical analysis to account for spatial dependence of data.

Soil samples were taken from the top of the mineral soil with cylindrical cores (5 cm diameter and 5 cm length) to obtain a known volume of soil. Subsequently, the soils were weighed and then stored at 4°C. We determined bulk density, soil pH, soil organic matter and soil moisture with standard methods within one week of sampling. Soil samples were homogenized by shaking before determination of soil moisture, soil organic matter and soil pH. Particle size distribution was determined on 50 g of oven dried soil using the hydrometer method. Oxalate-extractable Al and Fe were determined by atomic adsorption spectroscopy.

Phosphorus adsorption isotherms were used to determine the ability of the soil to remove or release phosphorus. To obtain this isotherm, 1 g air dry aliquots of each sample were placed in plastic vials containing 15 mL of PO₄ solution at concentrations of 0, 1, 3, 5, 7 mg P/L. After 24 hours of shaking and filtering the filtrate was analyzed for soluble reactive P colorimetrically. Phosphate was determined by the molybdenum blue method using ascorbic acid as a reductant. Total phosphorus (TP) in solution was determined by chemically oxidizing a portion of the filtrate to phosphate and analyzing colorimetrically. Dissolved organic phosphorus was derived as the difference between ortho-P and TP.

Equilibrium phosphorus concentration (EPCₑ) was computed from sorption isotherms obtained with the phosphorus data measured as described in the previous paragraph. This required the computation of sorbed phosphorus with the equation:

\[ S = (C_i - C_e) \]

where \( S \) is the amount of phosphorus sorbed, \( C_i \) is the initial concentration, and \( C_e \) is the concentration of phosphorus in solution after 24 hours of equilibration. Sorption was plotted against phosphorus concentration in solution. EPCₑ is defined as the solution concentration at zero sorption. Regression analysis was used to find this point.

A physical interpretation of EPCₑ is that it represents a reciprocal potential of soil to adsorb phosphorus. The larger EPCₑ, the less the ability of the soil to remove
phosphorus. If regression analysis does not give a positive slope, nor an x-intercept, i.e. EPC_0 does not exist, the soil is most likely a source of phosphorus.

We used both classical statistics and geostatistics to estimate the mean and variance of EPC_0, and the various soil properties. Normality of data was ascertained using the Kolmogorov-Smirnov (K-S) test. If the data was not normally distributed, non-parametric statistics were used. Unpaired t-test or the Mann-Whitney rank sum test were used, depending on the outcome of the K-S test, to test for seasonal differences in mean soil properties and EPC_0. Kruskall Wallis one-way analysis of variance on ranks was used to assess differences in mean soil properties and EPC_0 between drainage classes. Significant differences were evaluated at the 95% confidence level.

Geostatistical analysis was used for the first sampling date to model the spatial distribution of EPC_0, and soil properties that affect P release/retention. Estimation of areal means with Kriging is a preferred method when the data has a high degree of spatial structure.

Principal Findings and Significance:

Table 1 gives the result of classical statistical tests for soil properties in the three drainage classes and on the two sampling dates. Soil properties are not generally different between sampling dates for the same drainage class. However, between drainage classes on the same sampling date, soil properties are different. This is true not only for organic matter and bulk density but also for the soluble ion contents.

Kriged means for May were not significantly different to the mean values computed with classical statistics and they are not tabulated in this report. No krig analysis was carried out in November.

Table 2 lists the EPC_0 means and standard deviations for moderately well, somewhat poorly and poorly drained soils for May and November 1995. Each drainage class has different EPC_0 values in May and November. For somewhat poorly drained the x-intercept could not determined and sorption values remained below zero (denoted NI in Table 2) in November 1995. The soil in this drainage class was probably a phosphorus source in the Fall. Mean EPC_0 also varied between drainage classes. The best removal potential is in the poorly drained soils. The least potential for phosphorus removal is in the somewhat poorly drained soils.

Our first hypothesis listed above states that we anticipated some interaction between soil ions, organic matter and phosphorus. In Figure 1, EPC_0 is plotted against the
sum of oxidized Fe and Al and against % organic matter for the drainage class with the best removal potential (poorly drained). In May and November the soil oxidized ions appear to define a threshold for phosphorus removal. For [Fe] +[Al] > 8, EPC₉ₐ is low and thus the potential for removal of phosphorus is high. For [Fe] +[Al] < 8, EPC₉ₐ appears to increase asymptotically. Low organic matter coincides with low EPC₉ₐ and high organic matter coincides with high EPC₉ₐ. The other drainage classes are being investigated in a similar manner.

The graphs in Figure 1 give us confidence in that the more difficult to determine EPC₉ₐ values may be estimated from other soil properties. This would make a successful transfer of this technology to water resource managers more likely.

Utilization of Results:

It is our intent to use the information generated in phosphorus loading models to provide a source or sink estimate for riparian forested buffers. The finding that little can be gained from estimating average EPC₉ₐ values with spatial statistics, in our setting at least, makes a determination of EPC₉ₐ simpler since data points need not be surveyed and the non-standard geostatistical treatment can be omitted.

In a new project we will estimate the EPC₉ₐ averages for riparian forests down gradient from different land uses to determine whether different loadings lead to phosphorus saturation of the soil and consequently to the soil becoming a source of P. The information gained in this project will help us design efficient sampling schemes that take into account the seasonal variation and the variation in drainage class.

Publications Generated:

Dissertation:


Conference Proceedings:

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The table shows the results of a study on soil properties, specifically focusing on the differences in soil properties between months. The study found that the soil properties varied significantly between months, with July being the month with the highest values and December with the lowest values. The table also includes a comparison of soil properties between different months, with July showing the least variation and December showing the most variation. The study concluded that the soil properties in the area are not significantly different between months.
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Table 2: Equilibrium phosphorus concentration (EPC) at zero sorption for moderately well, poorly damped spots in May and November, 1995.
SYNOPSIS

Project Number: 03

Starting 6-1-95
Ending 5-31-96

Title: Land farming Techniques for On Site Bioremediation of Hydrocarbon-Contaminated Soils: Laboratory and Field-Scale Evaluation

Investigators: Jose A. Amador and Calvin P. C. Poon
University of Rhode Island
Kingston, RI 02881

Focus Categories: NPP TS

Congressional District: 2nd RI

Descriptors: Bioremediation, Petroleum hydrocarbons, Soil farming, Environmental Control, On site treatment, Biodegradation, Pollution prevention

Problem and Research Objectives:

Contamination of air, surface water, sediment, groundwater, and soils with toxic and hazardous chemicals is a potential health and social-economic problem among all industrialized nations today. There are over 1,250 abandoned sites with toxic and hazardous chemicals and wastes in the National Priority List, and the number may potentially increase to over 32,000. There are millions of underground fuel storage tanks in the United States and a significant number of these tanks are leaking. Despite the regulatory efforts to decrease the release of toxic chemicals to the environment, significant environmental contamination has occurred. At the current rate of Superfund site cleanup and the removal of leaking underground storage tanks, the environmental contamination problems will be with us for a long time. In Rhode Island alone, there are 12 Superfund sites eligible for federal cleanup, 82 hazardous waste sites throughout the state requiring public cleanup, and another 220 hazardous privately owned sites. Most of the sites need cleanup to reduce their long-term effects on groundwater pollution. With federal and state mandates to cleanup these sites, soil contamination has to be eliminated so that a contaminated site can be restored to its clean state. A restored site can have significant economic value, e.g., the former Kettle Point Petroleum Products Terminal site will be decontaminated and redeveloped into a condominium development project. Before the site can be redeveloped, soil total petroleum hydrocarbons up to 53,000 ppm and BTEX (benzene-toluene-ethyl benzene-xylene) up to 1690 ppm need to be reduced to 1 ppm BTEX. This can be accomplished by using various chemical, physical, or biological techniques which emphasize the detoxification and destruction of the contaminants rather than the conventional approach of disposal. The selection of technology alternatives depends on the applicability and economics of the technology for the cleanup of a specific site.
Methodology:

This project investigates various techniques of land farming for soil decontamination of soils polluted with petroleum products, e.g., fuel oil, gasoline, kerosene, and related products. Land farming is a form of on-site bioremediation that relies on aerobic microbial metabolism for the oxidation of the petroleum products. The factors governing the design, operation, and success of land farming technology include biodegradability of the contaminants, use of indigenous or imported bacterial consortium, control of moisture, pH, nutrient supplements, control of fugitive VOC emissions, and labor requirement.

(1) Laboratory-scale investigation

Contaminated soil samples and clean soil near the site at the Aquatic Tank Farm site of the former Naval Air Station at Quonset Point, Rhode Island were obtained. Laboratory-scale optimization of conditions for land farming can be accomplished initially using static microcosms. The information obtained from these microcosms will then be used to develop optimal conditions for field-scale implementation of the various land farming techniques.

The indigenous microflora of the contaminated soil was used to accomplish the aerobic biodegradation of the hydrocarbons. The site was contaminated by jet fuel JP-5 and aviation fuel. Because of the poor soil at the site, nutrients in the form of a fertilizer with N to P ratio of approximately 5 times were added to give an organic carbon/N/P ratio of about 100/15/3. Most samples did not require pH adjustment as the measured pH was within a range of 5.8 to 6.8. Outside of this range, lime was added to the soil sample to near neutral pH. The following non-ionic detergents were added to groups of soil samples: Dawn holding 25% by weight of surfactant, Sunlight holding 15% surfactant, Tide holding 25% of surfactant, and BioSolve holding 15% of surfactant. The amount of surfactants in the soil was controlled to 1.0, 1.5, 2.0, 2.5, and 3.0% of soil weight. All soil samples were moisture adjusted to about 60% of the soil's water holding capacity to start the experiment. Mercury chloride was added to the negative control sample in an amount of 1,500 mg/kg of dry contaminated soil. Positive control samples consisted of uncontaminated soil adjacent to the site subject to the same treatment as contaminated soils. The samples were put into sealed glass serum vials as static microcosms and incubated at room temperature. Rates of microbial respiration were determined by measuring changes in CO₂ concentration in the headspace of the vials as a function of time. The laboratory-scale study lasted 5 weeks and was terminated when the CO₂ generation rate diminished and stabilized.

(2) Field-scale investigation

Two windrow soil piles each 18-ft by 4-ft at the base and 3-ft high will be constructed at a jetfuel and aviation fuel contaminated site. Each soil pile will be divided into two portions. One half of the pile will be a control while the others will receive surfactant, nutrient, or moisture control. Gypsum block probe connected to a conductivity meter will be used for field moisture monitoring. Another soil pile 12-ft by 12-ft and 1-ft high simulating area farming will also be constructed. No soil turn over will be attempted for this pile. Again the area soil pile is divided
into two halves with one half for control and the other half with additions of surfactant, nutrients, and moisture control. Spatial and temporal samples will be taken to determine the total petroleum hydrocarbon degradation for all soil piles.

Principal Findings and Significance:

In the laboratory-scale study, the CO\textsubscript{2} generation was measured weekly in each of the microcosms. The gas generation expressed in terms of mg of CO\textsubscript{2} per g of soil for each microcosm was compared with a similar microcosm with different surfactant and different surfactant concentration and with the control.

The positive control microcosm, i.e., uncontaminated soil with the same moisture, pH, and nutrient control but without detergent, showed strong bacterial action. Within the range of surfactant used in the experiment, from 1.0 to 3.0 \% of the soil weight, it was found that the surfactant inhibited the bacterial action.

For the microcosms with contaminated soils, the surfactant in general enhanced the biodegradation of the hydrocarbon. However, Tide appeared to have too much disinfectant in the detergent such that the bacterial action was significantly inhibited. For the other three detergents, surfactant 1.0 to 1.5\% appeared to be the optimal concentration for enhancing hydrocarbon biodegradation in soil. At higher concentration, the detergent inhibited the bacterial action. Among these three detergents, Sunlight, Dawn, and BioSolve, BioSolve appeared to be slightly better.

There is a delay in the field scale investigation because of difficulties in gaining site access. Negotiations with federal agencies and state agencies are under way to get approval. Once site access is granted, the field work can be completed in about 8 to 9 weeks.
SYNOPSIS

Project Number: 04
Start: 6-1-95
End: 5-31-96

Title: Wellhead Protection from Nitrate Contamination through Minimum Fertilization of Turf

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

Focus categories: GW; NC; NPP; NU; WQJ.

Congressional District: 2nd RI

Descriptors: Ground water pollution; Nitrates; Land application; Organic Wastes; Aquifer; Fertilizers; Turfgrasses

Problem and research objectives:

Land development in southern New England is of such intensity that most areas are or soon will be subjected to some level of use. Shallow aquifers, especially those representing sole-source water supplies, need special protection but the land overlying them is often highly valued for residential or commercial development. It is important to identify those land uses which constitute the least threat to these sensitive water resources. Turf culture (residential, commercial, institutional and recreational) has come under much media criticism as an environmentally risky land use wherever ground water protection is important. This has influenced land use planning policy in spite of an ever growing body of research which shows turf to be a relatively effective ground cover for minimizing both nitrate and pesticide leaching to ground water.

While turf may constitute an environmentally sound ground cover over high value aquifer systems, it is important that managers of turf and those responsible for protecting ground water resources understand the best cultural practices for minimizing nutrient release from turf areas. Such knowledge will maximize the protective functions of turf and permit policy makers to assure the public that effective safeguards for wellhead protection and
preservation of water quality are being implemented. Most research has concentrated on quantifying the discharge of pollutants into ground water. This study will define fertilizer management strategies for turf culture which are most protective of ground water quality.

Research supported by the RIWRRRC over the past seven years has generated a substantial data base of monthly nitrate concentrations in soil water under intensively managed lawn turf. This information, along with annual nitrogen budgets generated for turf-soil ecosystems in Rhode Island and elsewhere, provide the basis for modifying turf fertility management so as to minimize nitrogen use. The objectives of this research are:

1. To minimize nitrogen fertilizer use on turf by applying it only when soil nitrogen supplies are not adequate to maintain turf quality. Emphasis will be placed on spring and early summer applications with less use in the fall.
2. To compare fertilizer sources for their ability to deliver nitrogen in the amount and at a rate required by turfgrasses. Readily available and slow release organic nitrogen sources will be compared.
3. To determine if good quality Kentucky bluegrass turf can be maintained with annual nitrogen applications of not more than 1 lb N/1000 sq-ft (less than 50 lbs. N per acre).

Methodology:

*Experimental design, plot area and treatments:* The plot area utilized for this research is located on the Turfgrass Research Farm of the Rhode Island Agricultural Experiment Station at Kingston, RI. The soil type is an Enfield silt loam (Coarse loamy over sandy skeletal, mixed, mesic, Typic Dystrochrept). The site had been in turf for the past 25 years but not utilized for experimentation since 1989. In early April, 1994, existing sod was killed by a topical application of glyphosate [N(phosphonomethyl)glycine] and the dead turf removed with a sod cutter. The site was limed and prepared for sodding. Commercially grown Kentucky bluegrass (Poa pratensis L.) sod was installed on April 26, 1994. The sod was grown within 500 yards of the plot site using a commercial blend (Lofts Seed Inc.) consisting of 25% by weight 'Suffolk', 25% 'Sydsport', 25% 'Baron', 15% 'P-104' Kentucky bluegrasses and 10% 'Jamestown II' Chewings fescue. Past experimentation has shown Kentucky bluegrass to be least efficient in recovering nitrate from solution and the most demanding of fertilizer nitrogen. If Kentucky bluegrass turf can be maintained at 1
lb N/1000 sq-ft/year, the same can be done with any cool-season turfgrass.

Seven nitrogen fertility treatments were initiated on June 20, 1994 and maintained to the present. These are summarized below:

<table>
<thead>
<tr>
<th>N source</th>
<th>Rate</th>
<th>Time &amp; amount applied (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea</td>
<td>3</td>
<td>June - 1.0; Nov. - 2.0</td>
</tr>
<tr>
<td>Urea</td>
<td>1</td>
<td>April - 0.5; June - 0.25; Sept. - 0.25</td>
</tr>
<tr>
<td>CORON</td>
<td>1</td>
<td>April - 0.5; Sept. - 0.5</td>
</tr>
<tr>
<td>CORON</td>
<td>1</td>
<td>April - 0.5; June - 0.25; Sept. - 0.25</td>
</tr>
<tr>
<td>Compost</td>
<td>1</td>
<td>April - 0.5; June - 0.5</td>
</tr>
<tr>
<td>Compost</td>
<td>1</td>
<td>April - 0.5; June - 0.25; Sept. - 0.25</td>
</tr>
<tr>
<td>Control</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

The 3 lb urea-N treatment simulated conventional fertility management for a home lawn. Urea is a water soluble, readily available, and inexpensive nitrogen source commonly included in commercial turf fertilizers. CORON is a liquid methylene diurea product, 28% N by weight of which about 30% is urea and 70% is a controlled release polymerized material. In our research, it has supported good quality turf, provided little leachable nitrate, and is the sort of nitrogen formulation popular with lawn service companies. The compost used was Earthgro Lawn Food with an analysis of 8-2-4. It consists mostly of composted leaves and poultry manure fortified with NaNO3. Its 8% nitrogen is about 50% water soluble and 50% insoluble. It is typical of commercially available 'organic' lawn fertilizers and in our research, has supported good quality turf but tends to leach some nitrate. These nitrogen sources represent the spectrum of materials currently used in lawn fertilizers and were intended to provide a realistic assessment of minimum fertility turf management. In this study, most fertilizer was applied in the spring when soil nitrate concentrations are lowest and absorption by grass roots is greatest. Low applications in September are intended to enable grass to recover more quickly from summer injury to the root system caused by drought, high temperatures, insect predation and human activity. An unfertilized control plot was included in each of the four replications to monitor natural seasonal changes in soil mineralization of organic nitrogen and normal fluctuations in soil water nitrate levels.
Nitrate Leaching, Nitrogen Recovery in Clippings and Turf Quality:
Suction cup lysimeters were installed in each plot at a depth of two feet on June 1, 1994. Soil water samples were collected monthly, weather permitting, and more frequently during the growing season. These were analyzed for nitrate-N and the results used to estimate nitrate leaching by multiplying the soil water nitrate concentration by leachate volumes calculated from the CREAMS model.

Clippings were harvested on four dates in 1994 and about every two weeks during subsequent seasons from a 10.3 sq-ft area of each plot. They were oven dried, ground to pass a 30-mesh screen and analyzed for total Kjeldahl nitrogen. Nitrogen recovered in clippings is a nondestructive means of estimating nitrogen absorption by roots and transport to shoots and for monitoring the nutritional status of turf.

All plots were scored for visual quality on four dates in 1994 and about once monthly during subsequent growing season. Quality scores constituted a subjective integration of turf color, texture, uniformity and freedom from weeds, disease and other injury.

April applications were made on 13 April 1995 and 1 April 1996. Mid-June nitrogen applications were made on 20 June 1994, 15 June 1995 and 14 June 1996 with the late summer applications made on 1 September 1994 and 1 September 1995. The November applications to the 3 lb. acre-N plots were made on 17 November 1994 and 24 November 1995.

Principal findings and significance:

This project is continuing through the 1996-97 year with funding from the RIWRRC under a different title. Consequently what is presented here can only be viewed as a progress report for the year 1995. This research realistically will require three to four years to test the minimum fertilizer hypothesis on which this project is based.

Turf quality:
Turf quality scores were taken on eight dates in 1995. While the late spring of 1995 presented near normal temperatures and slightly below normal rain fall the summer was warmer than normal and dry (3.5 inches below normal). This resulted in a sharp decline in turf quality during August. However, the return to more normal
conditions in September along with the nitrogen application to three plots, resulted in a marked increase in quality.

Differences among fertilizer materials and times of application were generally significant but not consistent throughout the season. Urea generally produced the highest quality turf but the one-pound rate was often equal to or better than the three-pound rate. Earthgro Lawn Food (compost) treated turf benefited from the early September application and that advantage persisted throughout the season. Coron treated plots exhibited a similar pattern with the 0.5 lb application in September producing a slight advantage over the 0.25 lb treatment. By mid- to late-fall, all plots exhibited good quality turf indicating that soil water nitrogen was more than adequate to meet grass needs. The unfertilized plots demonstrated the capacity for mineralized nitrogen to provide sufficient nitrogen. Only in the spring did these plots rank poorest. Later in the season, unfertilized plots were of higher quality than some receiving nitrogen fertilizer.

These results are from the first full post-establishment season and must be regarded as preliminary.

Soil water nitrate and nitrate leaching:

Soil water samples were collected on 15 dates in 1995 and the nitrate-nitrogen concentrations determined. Because of warmer than normal conditions throughout the summer, soil mineralization of organic nitrogen probably contributed to elevated soil water nitrate levels. Even the unfertilized plots contained soil water nitrate-nitrogen in excess of 1.0 mg NO₃⁻N/L (ppm) during late summer and fall. During the spring, nitrate-nitrogen levels were consistently less than 1.5 ppm. The higher urea-nitrogen treatment was evident by its elevated soil water nitrate levels. The 1.0 lb urea-N/1000 sq-ft application in mid-June resulted in a nitrate-nitrogen concentration in soil water of 16 ppm the following July.

All 5 g N/m² (1.0 lb N/1000 sq-ft) application rates failed to produce soil water nitrate-nitrogen levels in excess of 10 ppm NO₃⁻N set by the US Public Health Service as the maximum allowed in drinking water. Because of low rainfall during the summer months, nitrate leaching to the 2-ft. depth of the suction lysimeters may have been delayed or not detected even if nitrate levels in the surface soil horizons were relatively high. This may explain why the Earthgro compost plots which received 0.5 lb, N in mid-June did not exhibit
elevated soil water nitrate until August. The relatively high nitrate concentrations in soil water of Earthgro Compost treated plots probably is a result of the readily soluble sodium nitrate added to increase the analysis of that product. Even so, the nitrate-N level from those plots rarely exceeded 5.0 ppm.

**Nitrate Leaching:**

Nitrate leaching was estimated based on soil water nitrate concentrations and net percolation estimated from the CREAMS model. Almost half of the annual precipitation and irrigation was estimated to have percolated through the soil during 1995. This carried with it nitrate-nitrogen ranging from 4.3 g/m² for the high rate of urea to 0.6 g/m² for the Coron treatment in which most was applied in the spring. This represented quantities equivalent to 29% and 12% of the nitrogen applied, respectively.

Because nitrate concentrations in the soil water were so low in the spring, relatively little nitrate leached during that season. Also, precipitation was low resulting in only 1.6 inches of percolation. The greatest percolation occurred in the fall when soil water nitrate levels were highest. This resulted in nitrate leaching in excess of 1.5 g N/m² from the Earthgro Lawn Food when half had been applied in early September. The least leachable nitrogen source was Coron which lost less than 25% of that applied.

The leaching levels observed in this study were greater than those noted in other experiments conducted as part of this long-term investigation. In part, this was due to the low nitrogen rates applied. When expressed as a percent of that applied, even low leaching levels may appear large. Also, the high temperatures and dry conditions which characterized the 1995 growing season, probably contributed to rapid and extensive root decline while encouraging mineralization of soil organic nitrogen. This lack of roots reduced nitrate uptake by the turf leaving soil nitrogen vulnerable to leaching. The 1996 season having more normal precipitation and cooler than normal temperatures should promote greater root retention and activity with less nitrate leaching. This appears to be occurring.

Clipping samples harvested during 1995 have been processed and total Kjeldahl nitrogen analysis completed but as of this writing the data have not been analyzed.
Utilization of Results:

Since this research is currently only in its third year, utilization by industry or commercial practice is premature. However, the stage has been set for the concept being tested in this research to be applied to commercial turf management. Articles published in regional and national newsletters have alerted turf managers to the prospect of greatly reduced nitrogen use in turfgrass culture (see publication list). As results emerge from this project, they are being released to the commercial sector along with the theoretical bases on which minimum nitrogen turf management is predicated. The channels have been developed to expedite this information transfer.

Additional Funding:

While the RIWRRC is the primary source of funding for this research, other funding sources have been explored. These include:

1. Earthgro Corp. - $3,000 requested for 1996 along with fertilizer materials to support nitrogen efficiency research.

2. RI Agricultural Experiment Station - $1,500 in operating funds for research on nitrogen use efficiency in turf management.

3. TruGreen-ChemLawn Corp. - $3,000 requested to support 1996 research.

4. Student assistance for the 1996 season is being funded by the URI Turfgrass Foundation.

5. Research grants to support greatly expanded aspects of this project have been submitted to the the U.S. Department of Agriculture - Competitive Grants Program. This proposal is still pending. Grants submitted to the New England Golf Course Superintendents Association and to the Water Resources Research Regional Competition were not funded.
SYNOPSIS

Project Number: 05

Title: Silver Recovery/Removal from Photo Imaging Industries

Investigator: Calvin P. C. Poon and Rui-guang Guo
University of Rhode Island
Kingston, RI 02881

Focus Categories: TRT

Congressional District: 2nd district

Descriptors: Silver, Adsorption, ion exchange, activated carbon, electrodeposition, industrial wastes

Problems and Research Objectives:

Silver bearing waste are generated from photo-processing, X-ray processing, metal plating, and printing industries in Rhode Island and elsewhere in United States. The USEPA has designated 5 mg/l of silver as hazardous. However by taking into consideration of the silver toxicity in sewage treatment plant, silver content in sludge, silver toxicity in receiving waters, many sewer authorities have set silver pretreatment standards much lower than 5 mg/l. Currently the Narragansett Bay Commission has set pretreatment standards for silver at 0.43 mg/l maximum daily and 0.24 mg/l 10-day average. There is a proposal to lower the standards to a uniform concentration limit of 0.029 mg/l.

The major form of silver in the photo and X-ray processing wastewaters is silver thiosulfate. Most industries use metal exchange or electrolytic recovery to recover silver. Neither one of the techniques can remove silver down to less than 5¢ mg/l. Ion exchange is generally used to lower the silver concentration down to the pretreatment standards. However the ion exchange technology is expensive because of its limited exchange capacity for silver. Methods to increase the silver exchange capacity or using ion exchange technology in combination with other technologies for a more cost effective means of silver recovery is needed.

Methodology:

Silver bearing wastewaters were collected from various photo/X-ray processors in Rhode Island for study. Silver concentration of the wastewater and of the treated effluents of this study was determined by using Perkin-Elmer AA 3030 (flame) and 5100 (graphite tube). Depending on the objective of specific experiments, dissolved, particulate, total, or organo-complex forms of silver were determined. Sep-Pak C18 RPLC was used to separate the inorganic silver from the organo-complex form of silver, using methanol as the eluent.
Adsorption isotherm study was carried out for various materials including manganese oxides, activated carbon, and different types of resins. Silver nitrate solution was also studied for comparison of silver removal/recovery using actual silver bearing wastewater collected from industries. The resins giving the most promising results were selected for column study. Some experiments were conducted using the electrodeposition technique. The reactor consists of carbon anodes and stainless steel cathodes. The effluent from the electrodeposition process was then treated, with or without tap water dilution using ion exchange to lower the silver concentration down to 0.029 mg/l. Some experiments include acid fixing of silver onto the resin at breakthrough and the column was reused for silver exchange. The treatment and acid fixing cycles were repeated many times without having to replace the resin column at the end of each breakthrough. This in effect increased the silver recovery onto the column many times over the conventional technique used for ion exchange.

Principal Findings and Significance:

In the isotherm study, the Langmuir adsorption kinetic equation was used for data fitting as follows:

\[ \frac{1}{X_{eq}} = \frac{1}{X_m} \left( \frac{1}{K} \right) + \frac{1}{X_m} \]

The maximum adsorption capacity, \(X_m\) (mg Ag/g) and \(K\) value (1/mg of Ag) which is a measure of energy of sorption related to the heat of sorption, for each isotherm study are recorded as follow:

<table>
<thead>
<tr>
<th>Medium</th>
<th>Solution</th>
<th>(X_m) (mg/g)</th>
<th>(K) (1/mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5)-MnO(_2)(HCl)</td>
<td>Photo process, RA-4 solution Initial Ag conc 330 mg/l pH = 7.55</td>
<td>91.74</td>
<td>0.0058</td>
</tr>
<tr>
<td>GRC-22 12x30 mesh</td>
<td>Photo process, RA-4 solution Initial Ag conc 330 mg/l pH = 7.55</td>
<td>42.77</td>
<td>0.0129</td>
</tr>
<tr>
<td>(5)-MnO(_2)(HCl)</td>
<td>AgNO(_3) solution Initial Ag conc 200 mg/l pH adjusted to 7.0</td>
<td>192.76</td>
<td>1.13</td>
</tr>
<tr>
<td>(\alpha)-MnO(_2)(HCl + KNO(_3))</td>
<td>AgNO(_3) solution Initial Ag conc 200 mg/l pH adjusted to 7.0</td>
<td>138.06</td>
<td>0.066</td>
</tr>
<tr>
<td>GRC-22 200 mesh</td>
<td>AgNO(_3) solution Initial Ag conc 200 mg/l pH adjusted to 7.0</td>
<td>165.62</td>
<td>0.266</td>
</tr>
<tr>
<td>BL-pulverized 200 mesh</td>
<td>AgNO(_3) solution Initial Ag conc 200 mg/l pH adjusted to 7.0</td>
<td>110.64</td>
<td>0.172</td>
</tr>
</tbody>
</table>
The result indicates that using relatively high concentration of silver, 200 to 300 mg/l, all sorbents have a high adsorption capacity. Silver removal from pure silver solution as silver nitrate was much higher than silver from photo processing wastewater.

Mini-column and burette column studies were carried out using different types of resin and photo-processing wastewater (RA-4, a bleach-fixer solution combined with rinse water).

<table>
<thead>
<tr>
<th>Column</th>
<th>Ion Exchanger</th>
<th>Initial Ag Conc. (mg/l)</th>
<th>Breakthrough at 0.029 mg/l bed volume</th>
<th>Regenerant upflow</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini</td>
<td>IRA-68</td>
<td>37.7</td>
<td>150</td>
<td>30% NH₄,S,O₃</td>
<td>70.76</td>
</tr>
<tr>
<td></td>
<td>No pretreat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mini</td>
<td>IRA-68</td>
<td>38.86</td>
<td>570</td>
<td>same as above</td>
<td>83.14</td>
</tr>
<tr>
<td></td>
<td>4% H₂SO₄ treat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mini</td>
<td>Bio-Rad</td>
<td>37.8</td>
<td>630</td>
<td>same as above</td>
<td>99.57</td>
</tr>
<tr>
<td></td>
<td>No pretreat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mini</td>
<td>Bio-Rad</td>
<td>38.8</td>
<td>605</td>
<td>same as above</td>
<td>88.79</td>
</tr>
<tr>
<td></td>
<td>9 N HCl treat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buret</td>
<td>IRA-68</td>
<td>37.0</td>
<td>610</td>
<td>same as above</td>
<td>72.42</td>
</tr>
<tr>
<td>50 ml</td>
<td>4% H₂SO₄ treat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buret</td>
<td>Bio-Rad</td>
<td>37.0</td>
<td>600</td>
<td>same as above</td>
<td>--------</td>
</tr>
<tr>
<td>25 ml</td>
<td>No pretreat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mini</td>
<td>Bio-Rad</td>
<td>37.0</td>
<td>630</td>
<td>4N NH₄Cl</td>
<td>89.40</td>
</tr>
</tbody>
</table>

The results indicate that either manganese oxides or the powder form of activated carbon can be a stand alone treatment process for silver recovery. However 200-mesh size is too fine to be used in columns. Bio-Rad stands out as the most efficient ion exchange for silver removal in both its exchange capacity as well as ion exchange regeneration (using NH₄,S,O₃ 30% solution). However it is very expensive and could be prohibitive for industrial use.

IRA-68 appears to be the best candidate for use even though its silver exchange capacity is less than that of Bio-Rad and IRA-400. A cost-effective way of using the IRA-68 for silver recovery is to apply the silver bearing wastewater at about 300 mg/l of silver and remove it down to about 20 mg/l in columns. When breakthrough occurs, a 4% sulfuric acid solution can be used to fix the silver onto the resins. After the fixation and tap water washing step, the columns are ready to start the silver removal step again. This treatment/fix-regeneration cycle can be repeated up to 42
times in our experiments producing an effluent of the same quality, i.e., about 20 mg/l silver. The exchange capacity of silver has been significantly increased from 0.034 to 1.44 g of silver per g of resin. The shop owner, in effect, will be able to ship out a column to the silver refiner once in 3 years or longer instead of once a month provided that fix-regeneration at the shop is carried out. The spent acid contains less than 0.01 mg/l silver which in itself is not a toxic waste based on silver content.

The treated effluent containing 20 mg/l + 5 mg/l silver requires further treatment. As is, the effluent can not be treated using IRA-68 resin columns as efficiently as the photo processing wastewater. Apparently some residue accumulates in the effluent which reduces the treatment efficiency. It was found that some dilution of the effluent with tap water was a prerequisite for a further ion exchange treatment. Currently experiments are carried out to investigate the proper dilution with internal recycle which could consistently produce an effluent at 0.029 mg/l.

A laboratory built electrode position reactor was built with carbon anodes and a stainless steel cathode. The silver content of a strong photo processing solution at about 3000 mg/l can be reduced to approximately 250 to 300 mg/l in 24 hours. The silver recovered on the surface of the cathode can be scrapped off from time to time. This is a cost-effective way to recover silver from a high silver concentration solution. The eluent from the electrodeposition unit can be treated with the IRA-68 resin columns at two stages as described previously. A bench top pilot scale system will be used to carry out the experiments. The system design and operation is targeted to benefit the numerous small photo/X-ray processing shops for silver recovery and in compliance of the silver pretreatment standards in different states.
SYNOPSIS

Project Number: 06
Starting 6-1-95
Ending 5-31-96

Title: Pollution Prevention and Hazardous Waste Management for Marine Trade Industries

Investigators: Calvin P. C. Poon
University of Rhode Island
Kingston, RI 02881

Focus Categories: TS TRT M&S

Congressional District: 2nd District, RI

Descriptors: Marinas, Boat Builders, Pollution Prevention, Pollution Minimization, Solvent Recovery/Substitution, Process Substitution, Material Management,

Problem and Research Objectives:

Fiberglass reinforced plastic (FRP) boat building industry exists in Rhode Island for a long time. FRP production methods have been targeted for improvement because of the resin waste inherent during application, the liberation of volatile organic compounds (VOCs), principally styrene, during application and curing, and the need for large quantities of solvents, usually acetone, to clean spray guns and tools after completion of work. These issues represent regulatory and economic liabilities for the industry. Marinas in Rhode Island provide services to recreational sail and power boaters. Services include engine maintenance, painting, fiberglass repairs, pressure washing, and winterization and storage of vessels. Wastes such as waste oils, absorbents, antifreeze material, solvent, paints, pressure washing wastewater and human wastes from holding tanks are generated in various quantities. The boat building as a reemerging industry and the increasing boating activities in Rhode Island marinas all have a vested interest in reducing the liabilities of the pollution problem before regulatory and economic pressures impede the profitability of their business. In the environment of a sustainable industrial development and remaining profitable, pollution minimization and prevention are highly encouraged by both the regulatory agencies as well as the marine trade organization in the State.

Methodology:

Representative boat builders and marinas in Rhode Island were chosen for the study. The sites were visited including extensive interviews with the facility manager and production engineers. This site visits, coupled with an extensive survey form to be filled in by the facility manager, help to identify all processes that generate hazardous waste, the techniques and technologies to minimize and reduce waste generation, and finally recommend specific technology or process change tailored to each individual company’s needs in order to achieve the goal of waste
reduction and elimination. The entire process focused on how to reduce hazardous waste and VOCs while at the same time maintaining quality control. To accomplish this goal, we focused our research on alternative solvents, solvent reclamation, process substitution, and material management.

Principal Findings and Significance:

Solvent substitution-----Since acetone is a 100% pure solvent, it will volatilize over time and contribute significantly to VOC production. There are several acetone replacements suitable to many facility operations. (1) Shipshep is an organic based solvent with a slow evaporating rate and a high flashpoint, (2) Thermael is an aliphatic ester with a high flashpoint and can be used in a heated recirculating wash basin, (3) Green Stuff is a water based aqueous parts cleaner designed to be used in a heated recirculating wash basin. All substitute solvents are much more expensive. They are used a recirculating basin and should be reclaimed with an in-house still or commercially. Also flash gun or other demanding cleaning job would still require the use of a small amount of acetone or flash gun solvents.

Solvent reclamation-----Both in-house still and commercial distillation process are proven to be economic for acetone and other acetone substitute solvents reclamation. Cost recovery ranges from a few months to a few years depending on the quantity of solvent usage.

High volume low pressure (HVLP) spray technology-----Conventional air spray units currently used may have a transfer efficiency as low as 50%. Since VOC production varies directly with materials usage, any improvement in transfer efficiency decreases VOCs produced and resin required. Since HVLP spray technology can provide transfer efficiency of 70% or higher, this study provides economic and material saving analyses for many facilities.

Pressure fed roller resin dispensing-----Converting from conventional spray to pressure fed rollers for laminating procedures has advantages in material saving and VOC reduction. Although application rates of pressure fed rollers are lower than that of conventional spray technologies, it has been determined in this study that time saving from less cleaning and increased glass content of the finished product make up for the time difference. These rollers have also been determined to reduce the amount of VOCs emitted during lay-up.

Infusion molding-----The infusion molding process has been demonstrated to cut resin required and VOCs produced in the FRP process. Due to initial expenses, the process is only applicable for medium to large boat builders.

Solvent management-----Use of a centralized solvent wash basin is a method for controlling solvent usage. If the basin is covered and employs a tray to allow settling of particulate matter, evaporation reduction and useful solvent life can be optimized. If solvent has to be used at different location, the management should dispense the solvent to each employee in the smallest amount practical, and in a container that can be sealed or at least covered. The amount dispensed should also be consistent with the size of the job at hand, encouraging employee accountability for how the solvent was used.
Pressure washing-----Regulations proposed for implementation by 1999 by the Coastal Resources Management Council (CRMC) would require an 80% reduction of total suspended solids discharge from marina hull maintenance areas. Several commercially available treatment systems for pressure washing water have been identified with different capabilities including the removal of suspended solids, metals, and oil.

Recyclable program-----Encouragement of customers to participate in a marina sponsored recycling program can be fostered through easy accessibility to segregated recycling bins.

Secondary containment storage house-----Provide a dedicated storage shed, weather proofed, with an impervious floor and sufficient containment capacity to meet the Code of Federal Regulations requirements. Drop off bins clearly labeled should be provided under a cover directly outside of the storage area to avoid customers’ direct access inside of the shed.
INFORMATION TRANSFER

Title: Geophysical Methods for Hydrogeological and Contaminant Hydrology Applications

Principal Investigator:

Reinhard K. Froehlich
Department of Geology
University of Rhode Island
Kingston, RI 02881

Problem and Statement of Needs:

For the first time the information transfer effort is narrowly focused on one specific topic. The goal is to inform leaders and decision makers at the municipal, state, and federal level of government and people in the industry on the usefulness of surface geophysics. Groundwater exploration and the assessment, remediation, and control of pollution is associate with skyrocketing costs and call for reforms similar to those that have been suggested in health care.

Much of the work in hydrology is accomplished with test wells and chemical analyses. Geophysical surface methods provide cost-saving potential, and may eliminate the need for some of the more expensive borings and analyses. The report contains descriptions of Geoelectrics, Seismic Refraction, Gravity, and Magnetic Methods, field work and time requirements, equipments, interpretation, and application of these methods. Also included in the report is a comparison of expenses associated with drilling only as opposed to a combination of geophysics and drilling.

The product of this information transfer effort is a booklet of 51 pages with chapters organized as (1) Geoelectrics, (2) Seismic Refraction Method, (3) Gravity, (4) Magnetic Method, (5) References, (6) Recommended Readings, (7) Drilling, Sampling and Geophysical Exploration, and Appendix of Basics of Groundwater and Hydrogeology. The booklet is published for the purpose of bring the results of research in the past in near surface geophysics to those people who would most benefit from them.
COOPERATIVE ARRANGEMENTS

The Water Resources Center at the University of Rhode Island has two advisory committees, namely the State Advisory Committee and the University Water Resources Coordinating Committee. The membership listed below reflects the recent interest and availability of many water resources experts in Rhode Island:

**State Advisory Committee**

- Comb, Walter
- Falcone, William
- Delima, Virginia
- Mark, Eugene
- Meyer, Henry
- Millar, Scott
- Rose, Vincent
- Solomon, Eric W.
- Scott, Elizabeth
- Stuart, Everett
- Szynaski, Edward
- Weygand, Robert A.

RJ Dept. of Health  
RJ Water Resources Board  
US Geological Survey  
RI Audubon Society  
Kingston Fire District  
Office of System Planning, RI Dept of Adm.  
Save the Bay  
Ambrust Chain Co.  
Div. of Water Supply Management, RI DEM  
US Dept. of Agriculture  
RI Dept. of Environmental Management  
Lieutenant Governor

The state advisory committee consists of leading water resources officials of the state and federal agencies as well as representatives from prominent citizen groups and manufacturers.

The other committee is the University Coordinating Committee, consisting of faculty members of the University of Rhode Island from various colleges and the director of the Sea Grant program. Each member has a significant contribution to academic and research programs related to water resources area.

**University Coordinating Committee**

- Cain, J. Allen  
- Frohlich, Reinhard K.  
- Gold, Arthur  
- Miller, Robert H.  
- Nixon, Scott  
- Calvin P. C. Poon

Professor and Head of the State Geologist Office  
Professor of Geology  
Professor of Natural Resources Science  
Dean, College of Resources Development  
Professor and Coordinator of Sea Grant Program  
Professor of Environmental Engineering

The two committees discussed water resources issues and research priorities for the FY-1995 State Water Research Institute Program. As a result of the discussion and suggestions from the members, the research priority list was prepared and announced to the public as appeared on page 3 of this report. Both committees also reviewed and ranked research proposals, made comments and suggestions for proposal revision. They also serve as points of contact to collect and to disseminate information to various of audience.
Project 02 worked closely with US Department of Agriculture, Soil Conservation Service, USGS, and RI Department of Health.

Project 03 worked closely with RI Department of Transportation, RI Airport Corp., RI Dept. Of Environmental Management, US Army Corps of Engineers, and GZA GeoEnvironmental Inc.

Project 04 worked closely with the US Department of Agriculture, and Soil Conservation Service.

Project 05 worked closely with Division of Environmental Coordination of the RIDEM and firms of the photo processing industry in Rhode Island and Massachusetts.

Project 06 worked closely with the RI Dept. Of Environmental Management, and Dept. of Economic Development, RI Marine Trade Association, and many boat builders as well as marina owners/managers.
PUBLICATIONS

1. Book Chapters

Hull, R. J., 1996

2. Dissertations

Lyons, J., 1996
Temporal and Spatial Patterns of Retention and Release in Riparian Forest Soils, MS Dissertation, Department of Natural Resources Science, College Of Resources Development, Univ. Of Rhode Island, Kingston, RI.

Schultz, K. Douglas, 1996
Pollution Prevention Strategies in the Rhode Island Marine Fiberglass Reinforced Plastic Industry, MS Dissertation, Department of Civil/Environmental Engineering, Univ. of Rhode Island, Kingston, RI.

3. Water Resources Research Institute Reports

Gorres, J. and J. A. Amador
Completion Report, Riparian Wetland Forest Soils As Sinks and Sources of Phosphorus: Spatial Distribution Patterns and Modeling

Hull, R.
Completion Report, Wellhead Protection from Nitrate Contamination through Minimum Fertilization of Turf

Poon, C. P. C., and J. A. Amador
Progress Report, Landfarming Technologies for On Site Bioremediation of Hydrocarbon Contaminated Soils: Laboratory and Field-Scale Evaluation
Poon, C. P. C.  
Progress Report, Silver Recovery/Removal from Photo Imaging Industries  

4. Conference Proceedings

Hull, R. J., and H. Liu, 1995, Nitrogen Accumulation In a Turf-soil Ecosystem as a Function of N Source And Grass Species, Agronomy Abstracts 87:158

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02(FY-95)

Poon, C. P. C., 1994, Silver Reduction and Recovery For Photo Imaging Industries, Rhode Island Pollution Prevention Conference and Exposition, Providence, RI

03(FY-95)


06(FY-95)

6. Others

Hull, R. J., 1995, Minimum Maintenance Turf Management for Aquifer Protection, RI Turfgrass Field Day Field Book 64:5-13, Univ. of Rhode Island, Kingston, RI

04(FY-95)
### TRAINING ACCOMPLISHMENTS

#### Academic Levels

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