Puerto Rico Water Resources Research Institute
Annual Technical Report
FY 2004

Introduction

The Puerto Rico Water Resources and Environmental Research Institute (PRWRERI) is one of 54 water research centers established throughout the United States and its territories by Act of Congress in 1964 and is presently operating under Section 104 of the Water Research and Development Act of 1984 (P.L. 98-242). The general objectives of the Puerto Rico Water Resources and Environmental Research Institute are (1) to conduct research aimed at resolving local and national water resources problems, (2) to train scientists and engineers through hands-on participation in research, and (3) to facilitate the incorporation of research results in the knowledge base of water resources professionals in Puerto Rico, the U.S., the Caribbean, and Latin America as a whole. To accomplish these objectives, the Institute identifies Puerto Ricos most important water resources research needs, funds the most relevant and meritorious research projects proposed by faculty from island universities, encourages and supports the participation of students in funded projects, and disseminates research results to scientists, engineers, and the general public. Since its creation, the Puerto Rico Water Resources and Environmental Research Institute has sponsored a substantial number of research projects, supported jointly by federal, state, private, and University of Puerto Ricos funds.

The PRWRERI is a component of the University of Puerto Rico at Mayaguezs Research and Development Center. As such, it acts as official liaison of the University of Puerto Rico with industry and government for all water resources research activities. The Institute also functions as a highly recognized advisor to these two sectors on water resources issues. This role translates into multidisciplinary functions and activities that add relevance and impact to the research program the Institute supports.

By virtue of the local relevance of its research and the prestige and leadership of the investigators it has supported, the Institute has become the focal point for water-related research in Puerto Rico. Meetings, seminars, technical reports, and a quarterly newsletter are used by the Institute to keep the water resources community and general public informed about advances in research. Approximately once every two years, the Institute organizes major conferences on water-related research in Puerto Rico and the Caribbean, in collaboration with other technical organizations in the region. All these activities facilitate the translation of the research sponsored by the Institute into practical applications of direct benefit to industry, government, and the general public. The PRWRERI uses its website to make the Institutes work more widely known to, not only the Puerto Rican community, but to the whole world, and, at the same time, to provide means of information transfer with regard to the reports produced through the institutes research activities.

In addition to the 104 program, the PRWRERI conduct research in water resources and environment-related areas funded by a diversity of federal and state government agencies and industries. These non-104 program research activities comprise over 85% of the research funds at the Institute. Some of the most relevant research projects during FY2004 are as follows.

1. TMDL DEVELOPMENT FOR THE RÍO YAGÜEZ AND RÍO GUANAJIBO WATERSHEDS (sponsored by Puerto Rico Environmental Quality Board)

Section 303(d) of the Clean Water Act (CWA) establishes the Total Maximum Daily Load (TMDL) program. Federal law requires states to identify sources of pollution that make waters fail to meet state water quality standards, and to develop Water Cleanup Plans to address those pollutants. The Water Cleanup Plan (TMDL) establishes limits on pollutants that can be discharged to the water body and still allow state standards to be met.

To establish TMDL, the status of the water bodies needs to be determined a priori. Regulations allow states to select the water bodies as segments of a stream, lakes, reservoirs, wetlands, or watersheds. Of these, the watershed approach is encouraged. Once the watershed status is determined, the water bodies can be classified as impaired, or as in good health, based on the state water quality standards. For those impaired waters, TMDLs must be developed, according to state established priorities.

The Puerto Rico Environmental Quality Board (PREQB) is the state agency responsible of the TMDLs development in the Island. PREQB, in order to fulfill its responsibilities, has put together a task force whose constituents represent other state and federal government agencies such as EPA, USGS, DOH, NRCS, and the University of Puerto Rico, which is represented by the Puerto Rico Water Resources and Environment Research Institute (PRWRERI).

The tasks encompassed in this project concern to the first phase of the TMDL development. This phase has been denoted as PROBLEM IDENTIFICATION, which includes the compilation and evaluation of available existing data, the creation of a database to organize the colleted data, and the identification of additional data needed for the development of the TMDLs. By the end of this phase, a work plan for the next two years should be proposed and approved by PREQB.

The main objective of the first phase of the TMDL Development Project is to establish the current water quality status of the Río Yagüez and Río Guanajibo watersheds, based on existing data. Other small watersheds, such as Caño la Puente, Caño Boquilla, Quebrada Boquilla, Quebrada de Oro, Quebrada Llavat, and Quebrada Merle will be included in the study. This will allow the identification of the problem concerning the environmental health of the basins and the necessity of additional data. The knowledge acquired with the analysis and evaluation of these data will provide the foundations for the development of the TMDLs.

2. LAND USE CLASSIFICATION OF THE MAYAGÜEZ BAY WATERSHED (RÍO GRANDE DE AÑASCO, RÍO YAGÜEZ, AND RÍO GUANAJIBO WATERSHEDS) (sponsored by Puerto Rico Environmental Quality Board)

Remote sensing and Geographic Information Systems (GIS) are technologies that have provided an efficient tool to deal with spatial data. Remote sensing can be used to generate land use in a fast, low cost, and reliable way. GIS can be used to store, edit, analyze, and display the data. At the same time, the land use classification generated by remote sensing can be used as part of the GIS.

The Río Grande de Añasco, Río Yagüez, and Río Guanajibo watersheds are located on the west coast of Puerto Rico covering an area of 450 squared miles. The Río Grande de Añasco watershed covers an area of 257 squared miles, comprising portions the municipalities of Añasco, Mayagüez, Las Marías, Maricao, San Sebastián, Lares, Yauco, and Adjuntas. The Río Yagüez is located within the municipalities of

Mayagüez covering an area of 21 squared miles. The Río Guanajibo covers a surface area of 173 squared miles and is located within the municipalities of Maricao, San Germán, Sabana Grande, Hormigueros, Cabo Rojo, and Mayagüez. Theses three watersheds constitute the drainage area of the Mayagüez Bay.

In preliminary works done by the Puerto Rico Water Resources and Environmental Research Institute (PRWRERI), it was found that the biggest problems of contamination in the watershed are Fecal Coliform and sediments. Both of these can be related to human activities and to land use.

The last known effort toward the development of land use maps in this region was the Land Use Maps of the PR Planning Board of 1977, prepared by the US Geological Survey for the Soil Conservation Service. The main current land uses at the watersheds include urban areas (residential, industrial, and commercial areas), agriculture (crops, animal production, and pastures), and forests. During the last 25 years the watersheds have gone through diverse changes in land use. Land that was originally intended for agriculture is being changed to other uses, such as urban areas, especially in the lower portion of the watersheds at the coastal valley. Therefore, there is a need to identify the current status of the land use for the area. This is an important element of any management plan that could be developed at the watersheds.

The objective of the project is to develop a landuse classification for the Mayagüez Bay Watershed including the Río Grande de Añasco, Río Yagüez, and Río Guanajibo watersheds. Other minor tributaries to the bay, such as Caño la Puente, Caño Boquilla, Quebrada Boquilla, Quebrada del Oro, Quebrada Llavat, Caño Merle, and Caño Corazones, all small coastal watersheds between Río Grande de Añasco and Río Guanajibo river mouths, will also be included.

This classification may be used for many purposes. One immediate purpose is for modeling the fate of different pollutants generated within the watershed boundary. This is especially important for the development of Total Maximum Daily Loads (TMDL) management plans. Other purposes are development of management strategies, development of conservation alternatives, development of remediation strategies, hydrologic studies, and correlation analyses.

3. OPERATIONAL HYDRAULIC MODEL FOR THE SOUTH WESTERN REGION OF PUERTO RICO (sponsored by Puerto Rico Aqueduct and Sewerage Authority)

The management of water resources requires the conceptualization, planning, design, and execution of systems and structures able to supply the actual and future needs of the served population. Water is control and regulated to serve a variety of purposes, which contribute to enhance the quality of life, environment and economic growth. The population growth of the western municipalities of Puerto Rico, as well as the advance and development of the commercial and industrial activities, requires more and better water supplies, treatment and storage facilities, and distribution systems. The Puerto Rico Aqueduct and Sewerage Authority (PRASA), which is the government agency in charge to supply these services, is looking for efficient solutions to these problems.

In order to pose solutions for these water problems, it is necessary to know the actual condition of the existing systems. A very important and necessary tool to study the drinking water distribution problem is a hydraulic model of the system. This tool allows the integrated analysis of the different components of the system, including pipes, storage tanks, pumps, and valves. This model will also allows the analysis of alternatives and produce information to take decision to solve this problems.

This project proposes the development of a operational hydraulic model of the drinking water distribution system for the western region of PR. This model will become an analysis tool and will provide short and long term solutions. This project provides for the training of civil engineering student, which will be hired by PRASA after graduation to operate the model.

4. ADAPTING A COMPUTER-ASSISTED NON POINT SOURCE POLLUTION EDUCATIONAL PROGRAM FOR PUERTO RICO: MARINAS, ON SITE WASTEWATER TREATMENT, STORMWATER RUNOFF (sponsored by the Puerto Rico Department of Natural and Environmental Resources)

Nonpoint source pollution has been documented to be responsible for most of the contamination of surface and groundwater in the watersheds of Puerto Rico with agriculture as the principal land use activity. Eighty-seven percent of the surface water streams monitored in Puerto Rico for nutrient concentrations exceed the total phosphorous concentration limit for rivers of 50 micrograms per liter proposed by US Environmental Protection Agency (USEPA). Excessive phosphorus is attributed to overloaded or inadequately designed animal waste management systems, improper fertilizer land applications, and releases from improperly constructed or poorly maintained septic systems.

The entire island of Puerto Rico is classified as a costal zone, requiring the implementation of NPS water pollution management measures under the Costal Zone Act Reauthorization Amendments of 1990 (CZARA). This responsibility has been delegated to the Costal Zone Management Program of the Department of Natural and Environmental Resources. Shoreline and marina management, which include stormwater runoff and on-site wastewater treatment systems management (mostly septic systems), is critical to the islands fishing and tourism industries.

In Puerto Rico, the Water Resources and Environmental Research Institute has been working with partners from the University, Government agencies, and the private sector to improve water quality and satisfy the requirements of the Clean Water Act. The University of Puerto Ricos Agriculture Extension Service (AES) has been working with the State Department of Health and the USEPA to improve the private aqueducts of 300 communities that must achieve compliance with federal filtration and disinfection standards. Additional educational tools are needed to reach these and other audiences, such as local government officials, that are key to improving and protecting fresh and marine water resources.

Cornell Cooperative Extension responded to nonpoint source pollution control and stormwater management issues in New York State by developing LEAPE (Locally-led Education and Action for Protecting the Environment), which targets local government officials and community leaders with education about nonpoint source pollution control and provides management options for on-site wastewater treatment systems, streamsides, turf, local roads, marinas, and stormwater. The computer-assisted educational program uses resource information technologies, including geographic information systems, to encourage a watershed perspective and effectively illustrate nonpoint (NPS) source issues. The computer aids are highly interactive and education is conducted in a hands-on workshop with a set of laptop computers.

LEAPE addresses several issues of major concern in Puerto Rico, including on-site wastewater treatment systems (mostly septic systems), stormwater management, and marina management. This project proposes the adaptation off this model to Puerto Rico characteristics. A step towards accomplishing the adaptation was a two-day workshop prepared the County Agent to use the current version of LEAPE, including developing custom geographic information system (GIS) projects, modifying electronic slide presentations, and inserting some local information into files contained within LEAPE. Local officials have been looking into the advantages of adapting this model to Puerto Rico and its usefulness as a tool to be used in accomplishing the objectives of the CZARA.

5. WATER QUALITY MONITORING AND TESTING IN LATIN AMERICA AND THE CAROBBEAN COLLOQUIUM (sponsored by USEPA)

This project is a combined effort between the PRWRERI, the University of Puerto Rico, Pan American Health Organization (PAHO), and EPA, Cincinnati. It proposes to bring together water quality experts from all countries of Latin America and the Caribbean to establish the current status of water quality monitoring and testing knowledge.

Water related environmental problems are to be controlled to achieve specific environmental quality objectives. The field of water quality engineering (jointly with other water quality disciplines) has as objective to determine the environmental controls that must be instituted to achieve these environmental quality objectives. The problem arises principally from the discharge of human and natural generated residues, which, some how, interface with integrated uses of the water. Water uses, of course, are a matter of discussion and interaction between the social-political and economic environments and their ability to establish water quality standards that allow a region to live with, or otherwise improve, its water quality.

Some of the major water quality problems that have been perceived through interferences with some water uses are low dissolved oxygen, high bacterial levels, excessive plant grow (eutrophication), and high toxic chemical levels, among others. These water quality problems manifest as fish killing, nuisance odors, radical changes in ecosystems, disease transmission, gastrointestinal disturbance, carcinogens in water supply, etc. These water quality problems are subsequently confirmed through water quality sampling, monitoring, and analysis. Some of the water quality variables associated with these problems are BOD, NH3, organic N, organic solids, phytoplankton, dissolved oxygen, total and Fecal Coliform bacteria, viruses, metals, pesticides, herbicides, radioactive substances, and others.

So, the basic purpose of water quality engineers is to diagnose the type of problem, relate that problem to the water use interference, and then make a judgment on which water quality variables need to be controlled and the means available for control. To achieve this objective, it is of paramount importance that precise and accurate water quality sampling and analysis methods be available and properly used.

Water quality laboratories are a critical link of the whole process through which these objectives are to be achieved. If Latin America and Caribbean countries are considered in the water quality problem, few water quality laboratories are capable to produce data with the quality control and quality assurance required by U.S. regulatory organizations such as the Environmental Protection Agency (EPA) or state environmental quality boards. In addition, water quality data are not compatible from one country to another, limiting the sharing of data and international collaboration to tackle interbasin, or international, water quality related environmental problems.

There may be various reasons for this incompatibility, but as today, no efforts has successfully determined and resolved the source of this problem. Efforts like the water quality laboratories network (RELAC), with headquarter in Lima, Peru, has successfully bring together water quality laboratories from various Latin American countries into an international collaborative effort. Sponsored by the Pan American Health Organization (PAHO), RELAC has confirmed the necessary of training and standardization among the participating countries. Water quality method training is needed and, as well as, ways to manage, store, and share water quality data.

The University of Puerto Rico at Mayaguez (UPRM), through its Puerto Rico Water Resources and Environmental Research Institute (PRWRERI) proposes a colloquium where experts from Latin American and Caribbean countries can bring information about the needs their water quality laboratories have and share their experiences managing, storing, and sharing their data with other countries. The main objective of the colloquium is to bring experts from nations of Latin American and the Caribbean to identify current and future needs to improve water quality monitoring, control, and evaluation. The colloquium will be a 3-day closed meeting. Participation will be only by invitation. The conference will dedicate two days and a half to presentations on important issues on water quality, and half day to round table for discussion on the presentations and data provided by the invitees. The meeting will produce a report with all presentations, findings, discussions, recommendations, and conclusions.

Research Program

Only one project was funded under the 104b program. This project was completed within the reporting period and the next section presents the final report. Since promising findings were obtained, this project was continued, under a new proposal, for fiscal year 2005.

Sorption Behavior of Crumb Rubber to Remove Inorganic and Organic Contaminants from Aqueous Solutions.

Basic Information

Title:	Sorption Behavior of Crumb Rubber to Remove Inorganic and Organic Contaminants from Aqueous Solutions.
Project Number:	2004PR18B
Start Date:	1/31/2004
End Date:	1/31/2005
Funding Source:	104B
Congressional District:	N/A
Research Category:	Water Quality
Focus Category:	Water Quality, Toxic Substances, Treatment
Descriptors:	
Principal Investigators:	Oscar J Perales-Perez, Marco A. Arocha, Felix Roman

Publication

1. The Puerto Rican main newspaper EL NUEVO DIA (June 20th, 2005) published an interview to the research group.
2. Perales, O; Roman, F, and Alamo,Use of Recycled Crumb Rubber to Remove Heavy Metal Ions and Solvents from Aqueous Solutions, Poster presented at the 229th National Meeting of the ACS in San Diego, March 12-17, 2005

REPORT YEAR 1

Sorption Behavior of Crumb Rubber to Remove Inorganic and Organic Contaminants from Aqueous Solutions

Oscar Perales-Perez, Felix Roman, Marco Arocha

1. Project Summary

The present work was focused on the systematic evaluation of crumb rubber as a suitable material to remove inorganic and organic species from aqueous effluents through a low-cost and easy-to-scale technology based on the sorption properties of this waste material.

The capability of waste tires crumb rubber to remove metal ions of environmental concern in aqueous solutions was verified by adsorption studies at room temperature and quantified by ICP-OES. The chemical stability of mesh 14-20-crumb rubber was investigated for pH 1.5, 3, 6 and 9, before adsorption experiments. Final solutions were analyzed for Cd, Pb, Cr, Zn, As, Cu. In all cases, analyzed solutions reported concentration of those metals far below EPA regulations for drinking water. Sorption experiments verified that rubber particles (mesh 14-20 and mesh 30) were capable to adsorb Cu, Cd and Pb ions at different concentrations. The removal efficiency and metal-uptake levels were dependent on solution pH and metal concentrations. For instance, up to 98% of Cu(II) and Pb(II), and 37% of Cd(II) were removed from 1 ppm solutions of those ions and pH 6. It was also observed the continuous release of Zinc ions (from ZnO constituent in tires) during sorption tests. The adsorption capacity of crumb rubber was Pb > Cu > Cd, whereas higher metal concentration enhanced the metal uptake. Maximum uptake capacity for Cu and Pb ions at pH 6.0, were close to 0.6 mg/g rubber when the concentration of starting solutions varied from 1-20ppm. The adsorption efficiencies and metal up-takes were negligible at pH 1.5. Besides, crumb rubber was also used to remove xylene and toluene from aqueous solutions. The concentration of xylene dropped from 30 ppm down to 7 ppm in the first 30 minutes of contact. The terminal final concentration of xylene was as low as 2 ppm in a two-step operation. Preliminary results also suggested that sorbed metal ions can be desorbed by contacting 'pregnant' rubber particles with acidic solutions (pH 1-1.5) at room temperature.

2. Statement of the Critical Problem

Protecting water bodies (surface, aquifers and coastal) from contamination is essential for health and safety. Typical inorganic pollutants are heavy metals which form highly soluble solid products (e.g., Hg), or no solid at all (oxyanions like arsenite and arsenate, among others), after treatment of effluents by conventional alkaline precipitation. The limitations of conventional cleaning approaches become more evident when the contaminants are at very dilute concentrations as observed in effluents coming out from water treatment plants using conventional alkaline precipitation, or in ground waters polluted by hazardous species mobilized by leaching and/or percolation throughout soil substrates. Optional solvent extraction and ionic exchange systems are very expensive and they are tailored for high ion selectivity, which limits the removal of all contaminants through a single-step operation. In Puerto Rico, main problems of heavy metal pollution (mainly by Pb, Cu, Zn and Cd) have been reported in effluents from municipal wastewater, electroplating, metal finishing and printed circuit board manufacturing plants. In turn, the mercury pollution problem in Juncos and the presence of lead in some wells in Gurabo are examples of the aquifers contamination problem issue. The described situation is even more dramatic when the decontamination process deals with hazardous organic compounds, as those reported in some laundries and gas stations in Puerto Rico, where traditional precipitation and ionic exchange processes are not applicable at all. Accordingly, the development of a low-cost, environmental friendly and efficient cleaning process for effluents bearing inorganic and organic contaminants becomes indispensable.

About 4-million tires are discarded annually in Puerto Rico of them, approximately 800,000 tires are reused each year, and the remainder is land filled, stockpiled or illegally dumped. Land filling is a poor management option for scrap tires. Whole tires take up large amounts of valuable space in a landfill, coming up to surface shortly. New environmental regulations eliminate land filling as a disposal method, greatly increasing the environmental treat of scrap tires. Under this premises, the search of different alternatives to expand the re-use possibilities for scrap tires sounds justified.

The remediation option detailed in this proposal is based on the presence of components in crumb rubber, such as carbon black, zinc oxide, and sulfur, embedded in an elastomeric matrix, with potential capability to absorb/adsorb and precipitate hazardous species from aqueous solution. This fact has been verified by several investigations such as the research undertaken by Dr. James Donovan, a collaborator in this proposal. The sorbent material already cleaned and downsized to different particle sizes, will be kindly provided by Rubber Recycling and Manufacturing Corp., REMA, a Puerto Rican company that produces crumb rubber at different particle sizes from scrap tires. On this basis, the Phase-I of the present project dealt with the systematic investigation of the practical applicability for this 'waste material' to remove different inorganic, such as Cu(II), Cd(II), and Pb(II), as well as organic species of environmental concern. The applicability of crumb rubber as a sorbent will expand the recycling options for this material towards the treatment of polluted effluents (surface and underground) and remediation of contaminated soils where eventual superficial or underground water streams could have mobilized the contaminants into the aqueous phase.

3. Objectives of the Research (Phase-I):

This proposal explored the following main objectives:

i. To determine the chemical stability of crumb rubber in aqueous solutions at different pH values and room temperature.
ii. To asses the sorption capability of crumb rubber for inorganic and organic species from aqueous solutions. Targeted species were selected based on their chemical speciation behavior. Then, the sorption capability of granular crumb rubber for Cu (II), Cd (II), Pb(II), toluene and xylene, was investigated.
iii. To asses the sorption rates and loading-capacity as a function of crumb rubber particles concentration, particle size, ions speciation and concentration, solution pH in single-species systems at room temperature.

<u>Timeline of activities</u>

Year 1: Systematic evaluation of sorption properties of granular crumb rubber
1) Physical and chemical stability of granular crumb rubber in aqueous media (O. Perales-Perez, F. Roman).
2) Batch equilibrium and kinetic tests for sorption of inorganic species in single-species system (O. Perales-Perez, F. Roman)
3) Batch equilibrium and kinetic tests for sorption of organic species in single-species system (M. A. Arocha, O. Perales-Perez, F. Roman).

3. Methods, Procedures and Facilities

Methods and Procedures

Granular crumb rubber, screened at different mesh sizes, was kindly provided by REMA Corp. a tire rubber recycling company located in Caguas, Puerto Rico.

i. Chemical stability of granular crumb rubber
One 1 gram of screened crumb rubber (14-20 mesh) was contacted with 100 ml of distilled water under acid, neutral and alkaline solutions for 24 hours at room temperature. After contact, aliquots were withdrawn, passed trough a membrane filter and analyzed to determine the release of any inorganic species out from the sorbent.

ii. Experimental Procedures
The basic set-up for the sorption/desorption tests included temperature-controlled water shaker baths, stirrers, pH-meters and filtration and drying units. All quantitative analyses were carried out in Dr. Felix Roman's laboratory.

iii. Sorption experiments
The following parameters were evaluated in batch equilibrium sorption experiments: average size of rubber particles (mesh 14-20 and mesh 30), concentration of hazardous species (typically from 1 ppm to 30 ppm), pH (1.5 and 6.0, in inorganic sorption tests only). The typical crumb rubber concentration was 10g/l.

Synthetic solutions bearing targeted metal species were prepared in distilled/dionized water. Solution pH was adjusted by suitable amounts of NaOH or HNO_3 for the experiments with inorganic species. Synthetic metal ion solutions were prepared by dissolving suitable weights of $CuSO_4.5H_2O$, $CdCl_2$ and $Pb(NO_3)_2$ in de-ionized water. One-hundred ml of prepared solutions was contacted with 1 gram of crumb rubber in a temperature-controlled water bath shaker. Aliquots of 2.5 ml were withdrawn for different contact times to monitor the progress of the sorption process. All tests were run at room temperature conditions. Samples and blanks were run in triplicate. Depending on pH conditions, the solutions were acidified in order to retard hydrolysis reactions. The results of the sorption tests were used to determine the equilibrium uptake, sorption rates, and removal efficiency of target species.

The batch sorption tests for the organic compounds followed a procedure similar to that for inorganic species. However, screw cap vials with Teflon-lined septa were used instead of common glass beakers and agitated on a hematological mixer. In order to minimize vapor loss and allow a suitable mixing, the head space in the vial after addition of the sorbent and sorbate, was kept at approximately 1 ml. After contact period, samples were withdrawn, centrifuged in close vessels and submitted for quantitative analyses. Samples and blanks were run in duplicate.

iv. Quantitative analyses
Inductive Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) was used in this project for the quantitative evaluation of the sorption experiments. ICP-OES has multi-elemental capabilities, good sensitivity, high precision, accuracy, wide dynamic range and cost effectiveness. US EPA method 200.7 is an ICP-OES method used for the determination of heavy metals including Cu, Cd, Pb, in aqueous solutions. Individual standards and Standard Reference Materials were purchased from NIST or any other company that sales certified standards. The concentration of targeted

elements was measured before and after contacting the contaminants-bearing solutions with the crumb rubber to determine the sorption efficiencies and uptake capacities. The concentration of the organic compounds in the aqueous, gas and solid phases was determined by solid phase micro extraction (SPME) and gas chromatography mass spectrometry.

5. Principal findings and significance.

5.1 Chemical stability o crumb rubber.

Table 1 summarizes the obtained results. As seen, negligible release of toxic metals, such as lead or cadmium, was observed at pH 6.0 (typical pH value in surface and ground waters). In all cases, the concentrations are below EPA regulations for **drinking water**. Although Zn ions were released from the ZnO contents in crumb rubber, the concentrations were not above the accepted levels.

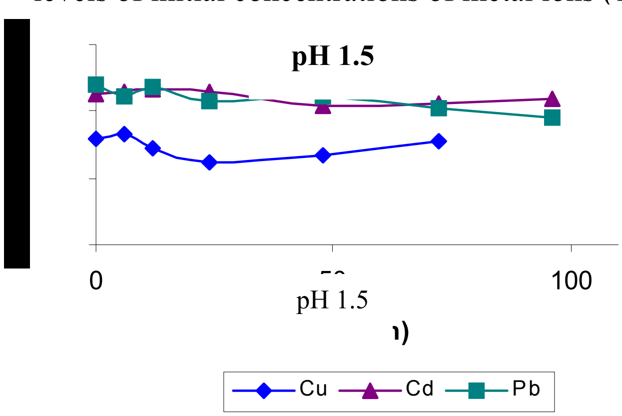
	Solution pH				
	1.5	**3**	**6**	**9**	**EPA regulation (mg/L)**
Cu	0.0828	0.0434	ND	0.0001	1.3
Cd	0.0023	ND	0.0010	ND	0.005
As	0.0372	ND	ND	ND	0.050
Zn	2.3842	1.1116	0.4080	0.2924	5
Pb	ND	ND	ND	ND	0
Cr	0.0518	0.0915	ND	ND	0.1

ND Not detected

Table 1. Concentration of metals released (mg/L) at different pH values. EPA regulations are for drinking water.

5.2 Sorption of inorganic species.

The purpose of these 'screening-tests' was to determine the sorption capability of crumb rubber in presence of select contaminant species in aqueous phase. Based on the obtained results, the contaminants up-take and sorption rate will be optimized during ongoing Phase-II. As suggested by the data showed in figures 1 and 2, our preliminary results confirmed the capability of waste tire crumb rubber to up-take Cu(II), Cd(II) and Pb(II) ions from aqueous solutions at room-temperature. Following figures show the variation of metal ions concentration with contact time for two different levels of initial concentrations of metal ions (1 and 5ppm).



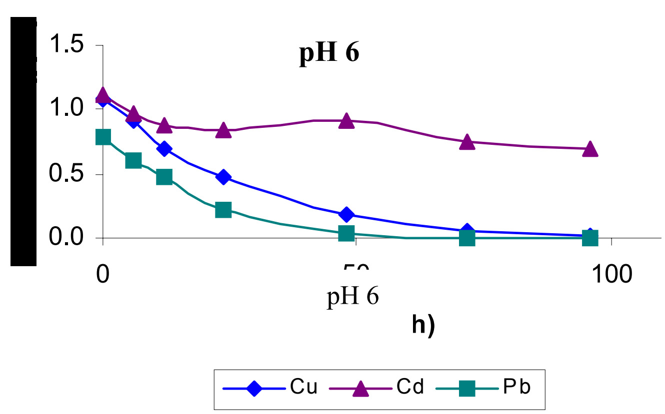


Figure 1. Sorption of Cu, Cd and Pb ions by 14-20 mesh crumb rubber (10 g/l). Initial concentration of metals ~ 1ppm.

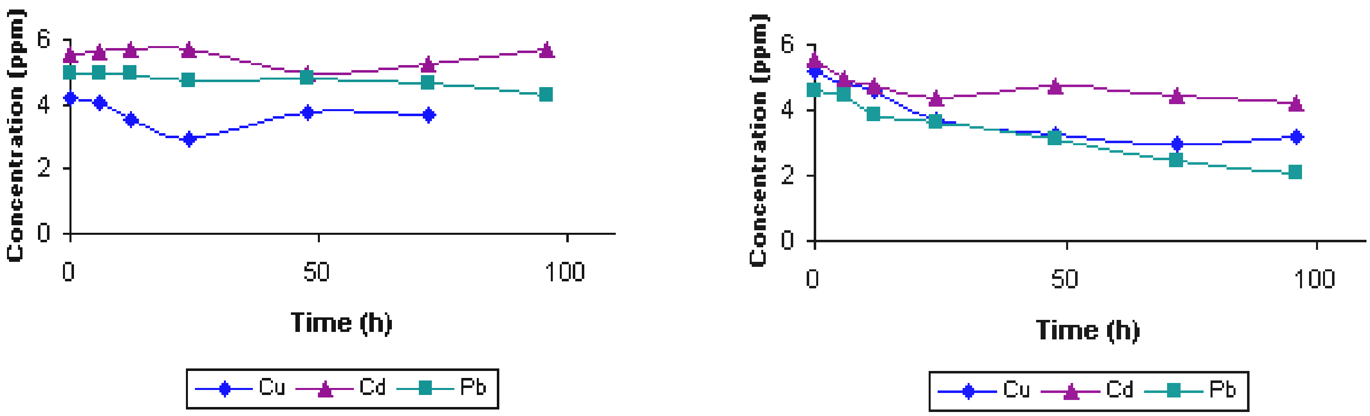


Figure 2. Sorption of Cu, Cd and Pb ions by 14-20 mesh crumb rubber (10 g/l). Initial concentration of metals ~ 5ppm.

As evident, the sorption behavior was dependent on the type of ion and pH of the starting solutions. The general trend showed a significant removal of metal ions at pH close to 6.0, which is in good agreement with the behavior observed in different adsorption systems where a more neutral pH favors the metals up-take and sorption rates. The sorption behavior was also dependent on the type of ions and an order of preference of crumb rubber for investigated metals was observed: Pb, Cu>Cd. The sorption trend becomes more evident for the most diluted initial metal ions concentration (~ 1 ppm), where hazardous Pb species was removed completely. The less mobility and large ionic size (0.97 A) of Cd species at pH 6 can explain the observed faster saturation of crumb rubber when Cd ions were adsorbed. In turn, the fast and continuous sorption of large-sized Pb ions (1.32A), expected to be strongly complexes by OH^- ions in neutral solutions, could be related to a different mechanism, that may involve ionic exchange with Zn sites available from ZnO in crumb rubber.

Other results for different initial concentrations of Cu(II) and Pb(II) species at pH 6.0 and mesh 14-20 crumb rubber are summarized in Figure 3. As seen, the lower the initial concentration, the higher the removal efficiency. These results evidence the capability of crumb rubber to adsorb/absorb heavy metal ions from aqueous solutions. The sorption kinetics and uptake capacities were enhanced even further when smaller particles size of crumb rubber (mesh 30) were used.

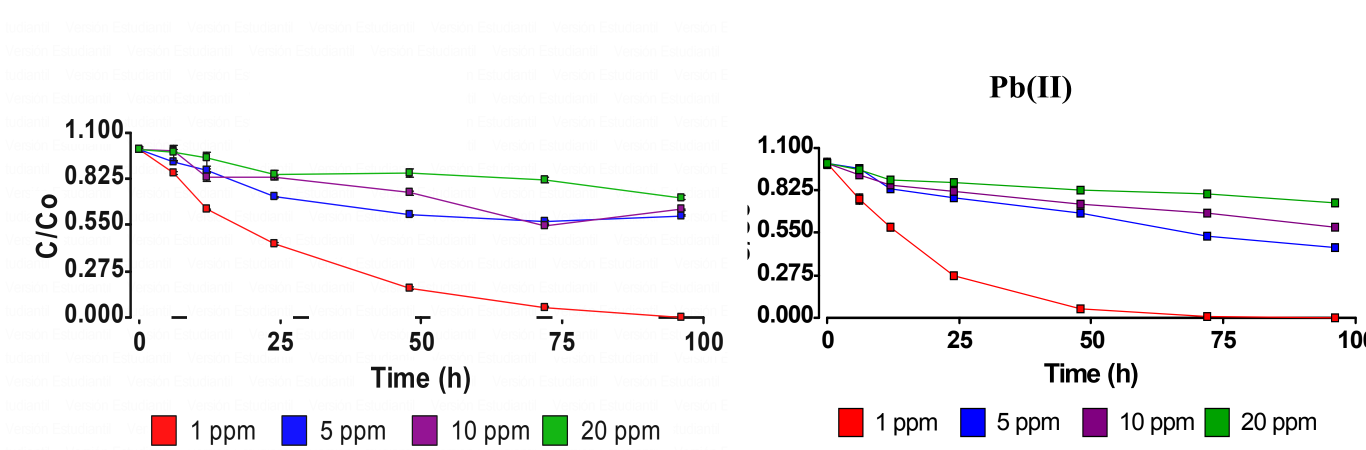


Figure 3. Sorption tests for Cu, Cd and Pb at pH 6.0 as a function of contact time at 25°C. The crumb rubber concentration was 10g/l for all tests.

On the other hand, the negligible sorption of Cu (II) and Pb (II) at pH 1.5 evidences the strong dependence of sorption capability with pH. The competition between H^+ and metal ions for available sorption sites could explain this behavior.

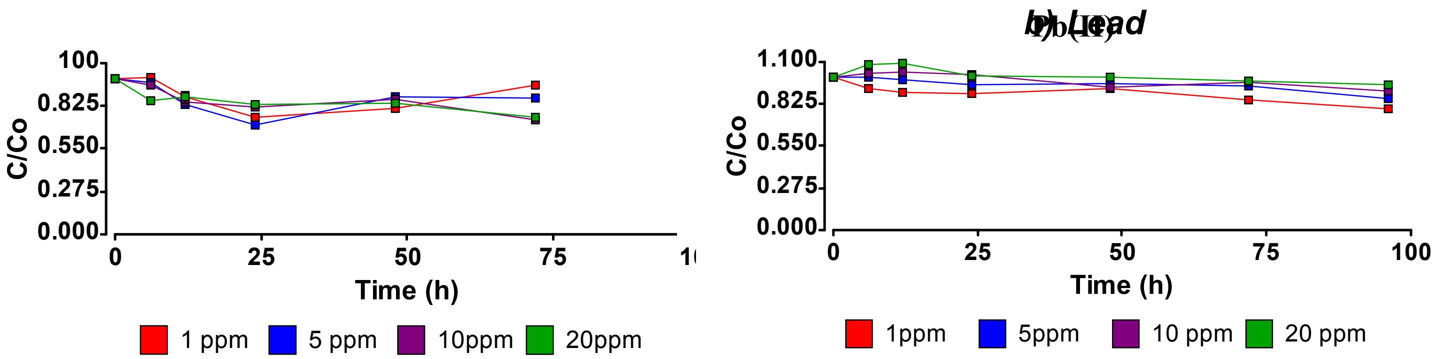


Figure 4. Sorption tests for Cu, Cd and Pb at pH 1.5 as a function of contact time at 25°C. The crumb rubber concentration was 10g/l for all tests.

The linear isotherms indicate the rise in crumb rubber uptake capacity (in mg/g) with the increase in the initial concentration of metal ions.

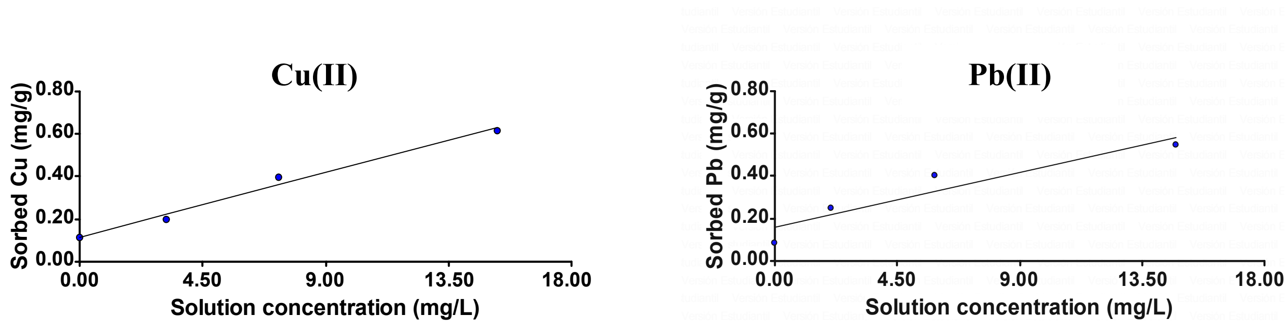


Figure 5. Sorption isotherms for Cu(II) and Pb(II) at pH 6.0.

5.3 <u>Desorption tests for Cu(II) ions</u>.

The presence of Cu in solutions after contacting 'pregnant' crumb rubber with distilled water at pH 1.5 suggested that desorption can be realized. An ionic-exchange mechanism should be involved with this process. Desorption option would enable crumb rubber to be regenerated and re-used in a subsequent sorption cycle. A more detailed evaluation of this option is included in ongoing Phase-II of the present project.

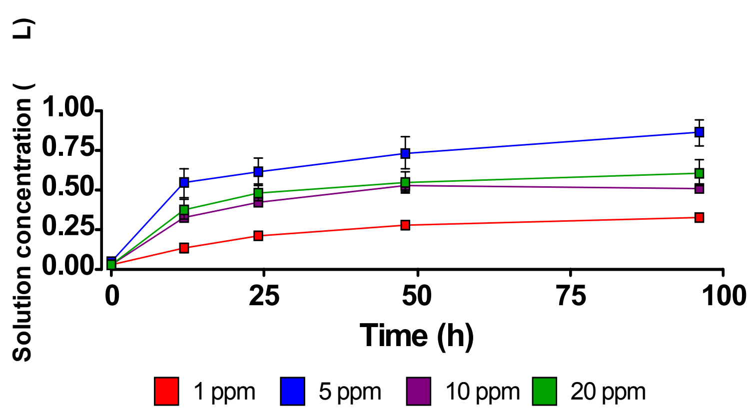


Figure 6. Cu(II) release after contacting crumb rubber, recovered from the sorption experiment at pH 6.0 and different initial concentrations, with an aqueous solution at pH 1.5.

5.4 Sorption of xylene and toluene

The sorption of organic species by crumb rubber was very fast. Most of the organics were sorbed within the first 30 minutes of contact. As evidenced by figure 7, the concentration of toluene can be decreased from 30 ppm down to 2 ppm in a two-step operation. Furthermore, the uptake capacity (in mg of xylene/g) of crumb rubber is high even at low concentrations of crumb rubber (Figure 8). Ongoing work addresses a more complete evaluation of the up taking capacity for toluene, xylene and benzene.

Step-I

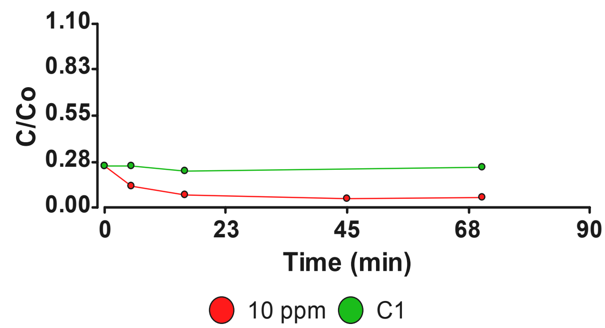


Figure 7. Sorption of Toluene by crumb rubber at pH 6.0. Initial toluene concentrations, 20 and 30 ppm (Step-I), and 10 ppm (Step-II). C1 and C2 correspond to control tests.

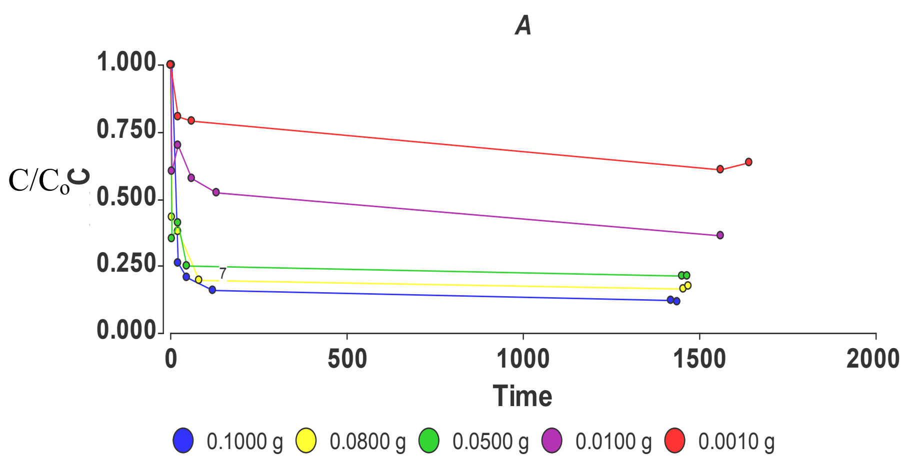


Figure 8. Sorption of Xylene with different amounts of crumb rubber in 10 ml of aqueous solutions at pH 6.0.

6. Publications:

6.1 A poster entitled: ‘Use of Recycled Crumb Rubber to Remove Heavy Metal Ions and Solvents from Aqueous Solutions’, was presented at the 229th National Meeting of the ACS (San Diego, March 12-17, 2005).

6.2 A poster entitled: ‘Use of Recycled Crumb Rubber to Remove Heavy Metal Ions and Solvents from Aqueous Solutions’ was submitted to PRWRERI. This poster included new data on sorption of organic species (xylene and toluene).

6.3 The Puerto Rican main newspaper EL NUEVO DIA (June 20th, 2005) published an interview to the research group.
6.4 A full paper with current findings is under preparation.

7. Other activities:

7.1 Toyota Foundation awarded to the research group the amount of $13,500 (01 year). The money is being used to cover stipends of graduate students participating in the project.
7.2 A full proposal was submitted to the Waste Solid Management Agency requesting funds for acquisition of state-of-the-art instrumentation. The proposal has been approved by the technical committee panel. Legal considerations to be included in the contract will hopefully be completed before July 2005.
7.3 A three-year proposal was submitted to USDA. Although the proposal got good reviews it was declined. The main observation was related to the lack of preliminary results at the time the proposal was submitted.
7.4 The PI plans to prepare a full proposal to be submitted to USGS and/or NWRI (November 2005).
7.5 Based on promising preliminary results, the research goals has been expanded to the evaluation of crumb rubber as potential sorbent for antimicrobials in aqueous solutions (Phase-II of the present Project).
7.6 The present research group involves: 03 faculties (02 from Materials Science and 01 from Environmental Chemistry) and 04 four graduate students from the UPRM-Chemistry Department. The PIs plan to include at least a couple of undergrad students from Chemistry and/or Civil Engineering Departments.

Information Transfer Program

This is a continuing project in which a course in practical applications of hydraulics and hydrology has been developed. Since the project is not finished, a progress report is presented.

The decision to grant a time extension for this project was greatly based on administrative problems that aroused and were out of the control of the PIs. The project required the drilling of two wells within the property of the University. Getting the permits from the university administration took more than a year. Although a course was created and taught, the sections on groundwater hydraulics could not be covered with hand on experience as originally thought. This portion of the course was covered theoretically.

Now the wells are drilled and operational and the course is scheduled to be offered again during the fall semester. The time extension granted will allow the PIs to adequately cover the groundwater sections of the course and completely evaluate the technology transfer.

FIELD METHODS IN HYDROLOGY AND HYDRAULIC

Basic Information

Title:	FIELD METHODS IN HYDROLOGY AND HYDRAULIC
Project Number:	2003PR13B
Start Date:	3/1/2003
End Date:	2/1/2004
Funding Source:	104B
Congressional District:	
Research Category:	None
Focus Category:	Education, Hydrology, Methods
Descriptors:	None
Principal Investigators:	Ingrid Yamill Padilla, Raul Zapata

Publication

Project Number: 2003PR13B

Start: 3/1/2003
End: 2/1/2004

Title: Field Methods in Hydrology and Hydraulics

Investigators: Padilla, Ingrid Y., Zapata, Raul

Focus Categories: Education, Hydrology, Methods

Congressional District:

Descriptors: Field Methods, Hydrologic Measurements, Hydraulic Measurements

Problem and Research Objectives:

The Department of Civil Engineering and Surveying at the University of Puerto Rico, Mayagüez begun a Doctoral program in Environmental and Water Resources Engineering during the year 2002. This program generated the need for a new and innovative curriculum of graduate courses to train scientist in these vital areas. It is also necessary to provide the students with practical field experience, which will bilaterally strengthen the theoretical and analytical skills developed during the forming years.

The Water Resources and Environmental Research Institute is taking an active role in promoting higher level education and helping to fill the gab between theoretical and applied engineering science. One major obstacle to fulfill this task is the lack of appropriate equipment for field measurements. By supplying instrumentation for the creation of the "Hydrologic and Hydraulic Field Measurement" course, this proposal is a step forward and a major contribution to improve the formation of new scientists in the water resources and environmental areas.

This project requested the instrumentation necessary to create an applied measurements course titled "Hydrologic and Hydraulic Field Measurement". The course objective is to provide graduate students from the MS and PhD program in Water Resources and Environmental Engineering with field experience in measurement of hydrologic and hydraulic parameters, as well as field reconnaissance work for research and applied engineering applications.

Methodology:

The course was initially created at the departmental and institutional level to be offered as an official graduate course. It was created as a graduate course that can be taken by entry-level M.S., as well as senior Ph.D. students having fundamental knowledge in hydraulics and hydrology. The course creation had involved four faculty members from surface water and groundwater hydrology and hydraulics.

Seven field/experimental activities were initially planned and scheduled as shown in the attached syllabus and briefly summarized in Table 1. Each of the field activities were preceded by a lecture explaining the methods to be used. The field/experimental activities were followed by periods of data evaluation, analysis, and documentation. All students were required to prepare written reports student for each of the activities. A presentation which integrates all field activities is required at the end of the semester.

Table 1. Field/experimental activities included in the course "*Field Methods in Hydrology and Hydraulic*".

Activity	Topic	Description
1	Climatic Variable Analysis	Students install a portable weather station, collect climatic data from this and other USGS' and NWS' weather stations around the island, and perform various data analyses. Climatic variables measured include rainfall, temperature, wind speed and direction, solar radiation, humidity, and vapor pressure. Lectures include techniques for collecting and presenting the data, operation principles of the instrumentation, and procedures for the analyses. The analyses include, but are not limited to, statistical analyses, completeness and consistency tests, and frequency analysis.
2	Evaporation and Evapotranspiration	Students take daily measurements from and maintain a Class A Evaporation Pan during the entire semester. The data collected is used to calibrate various evaporation models. The students model evaporation in different sites and assess the results. The models take into energy balance, aerodynamics, and combined evaporation principles. Evapotranspiration is assessed by means of a lysimeter built by the students. The data is used to calibrate some models and to develop relationships between evaporation, and actual and potential evapotranspiration. The data is also applied to determine the monthly pan evaporation coefficient.
3	Infiltration	The objective of this activity is to introduce students to (1) methods and instrumentations used to measure infiltration in the field; (2) assessment of infiltration characteristic of soils; and (3) development and application of infiltration models. Measurements are related to surface runoff, groundwater recharge, and groundwater flow processes in the vadose zone. Students install field infiltrometers and tensiometers, and perform infiltration tests on different types of soils. The data collected is used to assess the infiltration characteristic of the soils tested and to calibrate different empirical models. Parameter estimation of most commonly used models are emphasized.
4	Surface Water Hydraulic Measurement	Students are trained in the use of a variety of field equipments to measure fundamental hydraulic and geometric parameters, which are required for river or channel studies. The classroom lecture includes presentation and demonstration of the different field tests and their importance in river hydraulics. Several selected stream reaches are selected and surveyed by the students. Cross section elevation and station points are surveyed and located using GPS equipment for accurate location. Students learn to tale stage and stream discharge measurements using a stage markers, topographic surveys, and flow propeller. A depth sounder is used to obtain channel elevation below the water surface. The range finder and the inclinometer allow a quick estimation of the river width and the banks height.
5	Sediment Transport	Students are initially offered a review lecture on fundamentals of sediment transport, where the equipment and sampling procedures are presented and demonstrated. The lecture is followed by field reconnaissance of at least two sediment sampling sites. The sampling equipment is set at the selected sites and field measurements of discharge and suspended and bed sediments are taken to obtain sediment loads. Bed, bank and flood plain materials are collected from representative sites for sediment size distribution analysis in the laboratory. The students select, from previous class discussion, several sediment transport functions and apply them to the field data. Results are compared with measured values for selection of the more appropriate equations and sediment loads are modeled.

Table 1. Field/experimental activities included in the course "*Field Methods in Hydrology and Hydraulic*" – Continued.

6	Pumping and Specific Capacity Test	The objective of this activity is to introduce the students to: (1) groundwater measurements and instrumentation; (2) single point, field data evaluation; (3) analysis of temporal field data uncertainty; (4) analysis of single- well response to groundwater extraction; and (5) evaluation of well production (yield capacity) and efficiency. The specific capacity test involves pumping a production well at a given (design) flow rate while monitoring water levels, drawdowns, and flow rates at the well. Once water levels have reached "steady state" at the well for a given flow rate, the pumping rate is instantaneously changed to a higher flow rate while continuously monitoring water levels, drawdown, and flow rates. This procedure is repeated at least four times to establish the relationship between well yield and drawdown. Regression analysis and groundwater analytical models are then used to analyze the data and determine well yield capacity. This activity requires a pumping well dedicated for instructional purposes.
7	Aquifer Test and Groundwater Sampling	The objective of this activity is to introduce the students to: (1) spatial and temporally-synchronize field measurements; (2) groundwater system (aquifer) evaluation; (3) analysis of temporal and spatial field data uncertainty; (4) field determination of groundwater hydraulic properties; (5) evaluation of aquifer production and groundwater dewatering processes; and (6) groundwater quality sampling and measurement methods. The aquifers test involves pumping a production well at a constant rate for 2 days, while monitoring water levels and drawdowns at the pumping well and the nearby observation well. Flow rates at the pumping rate are also monitored throughout the test. Once the data is collected, it is analyzed using groundwater flow analytical models. Groundwater is collected at the discharge point from the production well and sampled from the observation well using a bailer. The samples are analyzed for temperature, pH, conductance, and TDS. The data is used to model aquifer properties and production capacity. This activity requires a pumping well and, at least, an observation well dedicated for instructional purposes.

Principal Findings and Significance:

The course was created as a Civil Engineering course (INCI 6116) and offered during the fall semester of the 2003-2004 academic year. Although a civil engineering course, it is open to graduate students from other areas, as long as they possess fundamental knowledge on hydrology and hydraulics concepts. Five graduate civil engineering students registered: 3 were at the M.S. level and 2 were at the Ph.D. level.

The course scheduled followed the attached *Course Syllabus* (Apendix 1). All field activities were conducted successfully as planned and described in Table 1, except for the last 2 activities related to groundwater hydrology ad hydraulics. The groundwater field activities were delayed because, although all the documentation was submitted months prior to the commencement of the academic semester, the permit for well drilling and installation was not obtained on time. This permit must be given by the Puerto Rico Department of Natural and Environmental Resources prior to any well drilling and installation activity.

Most of the field activities were successfully implemented and carried out. Students leaned about the instrumentation and methods of hydrologic and hydraulic field activities and applied theoretical concepts on the analysis of the measured parameters. Some problems were encountered in the installation and data analysis of the lysimeters and infiltrometers, but those problems have been solved for the next time the course is offered.

Although the issues related to the well installation permit have been resolved at this time, they were not resolved prior to the end of the academic semester when the course (INCI 6116) was offered. At the end of the semester it was then decided to extend the course to the following semester to allow time for permit approval and give the students the opportunity to conduct the proposed, groundwater-related activities. Unfortunately, the permits and contract were not issued on time and the proposed groundwater field activities were not completed. The students were taken to nearby observation wells, where they use groundwater and GPS instrumentation to measure water levels, well location, and elevation. The data obtained was used to determine groundwater potentiometric elevation and flow directions. Because this activity lacked a significant component of the proposed groundwater work, the field procedures and methods were thoroughly explained and data from other (real) specific capacity and aquifer tests were then provided to the students for analysis. The data provided was collected from pumping and aquifer tests conducted in the Rio Turabo basin in Caguas, Puerto Rico. This data is included in Appendix 3. Evaluation of the groundwater field work was based on the field work conducted in the nearby observation wells and on the data analysis of the specific capacity and aquifer tests.

A pumping and an observation well were installed in April, 2005 near the Civil Engineering building at the UPRM campus. The approximate location of the wells are shown in figure 1. Students from several courses, including those who were previously registered in the ***Field Methods in Hydrology and Hydraulic Measurements*** course, were invited to see the well installation equipment and methods. The well installation activity was recorded to be later shown in future classes. The construction parameters of the wells are summarized in Table 2. These wells will be used in future ***Field Methods in Hydrology and Hydraulic Measurements*** and Groundwater Hydrology Courses.

Table 2. Construction parameters of the wells installed

	Pumping Well	**Observation Well**
Borehole Diameter	10 in	6 in
Borehole Depth	95 ft bls	110 ft bls
Casing Material	PVC	PVC
Casing Diameter	6 in	2 in
Casing Depth Interval	0 - 65 ft bls	0-70 ft bls
Screen Depth Interval	65- 95 ft bls	70-110 ft bls
Filter Pack Depth Interval	5-95 ft bls	5-110 ft bls
Sanitary Seal (Grout) depth	0-5 ft bls	0-5 ft bls
Pump Capacity	40 GPM	NA
Pump Installation Depth	85 ft bls	NA

The learning objectives for the course were evaluated from written reports submitted by the students. The final grades were based on 6 individual written report grades. Because of the complications encountered with the installation of wells, and subsequent delayed of the course completion, students were not evaluated in the oral presentation. Future courses will include the presentation requirement. The general objectives of the course were accomplished in this project.

Students learned the practical and theoretical principles of hydrologic and hydraulic measurements in the field. This course has further exposed them to the instrumentation and difficulties and errors involved in field measurements and data interpretation. It has given them the basis to understand and visualize the data they often encounter for analysis and decision making.

TRAINING ACCOMPLISMENTS

Five students enrolled officially in the newly created course in ***Field Methods in Hydrology and Hydraulic Measurements*** as summarized below. Other students, however, have been indirectly trained from this project. Five other students registered in *Groundwater Hydrology* during the 2nd academic semester of 2004-2005 were trained in basic groundwater measurements (water levels). Other faculty members from geology and Civil Engineering and over 10 graduate and undergraduate students from chemical engineering, soil science, and civil engineering participated during the well drilling and pump installation and testing activities.

Field of study	Academic Level				Total
	Undergraduate	MS	Ph.D.	Post Ph.D.	
Chemistry					
Engineering:					
Agricultural					
Civil		3	2		5
Chemical					
Computer					
Electrical					
Industrial					
Mechanical					
Geology					
Hydrology					
Agronomy					
Biology					
Ecology					
Fisheries, Wildlife, and Forestry					
Computer Science					
Economics					
Geography					
Law					
Resources Planning					
Social Sciences					
Business Administration					
Other (specify)					
Totals		3	2		5

APPENDIX 1
INCI 6116:
Course Syllabus

University of Puerto Rico
Mayagüez Campus
College of Engineering

Syllabus & Instructor Information Sheet Form

A. COURSE SYLLABUS

1. General Information:

Course Number: INCI 6116
Course Title: Hydrologic and Hydraulic Field Measurement Methods
Credit-Hours: 3

2. Course Description:

This course provides graduate students at masters and doctoral levels the knowledge and skills required for using field equipment, sampling techniques, and data analysis for hydrologic and hydraulic applications. The course uses widely accepted and tested measurement techniques and equipment. The course provides students with useful measurement tools, skills for equipment use, and data analysis methodologies for climatologic, river hydraulics, and field measurements for their independent research needs. It requires extensive field work.

3. Pre-requisites: None

4. Textbook, Supplies and Other Resources:

Class Notes

5. Purpose:

The purpose of the course is to provide students with useful measurement tools, skills for equipment use, sampling techniques and data collection and analysis in hydrologic and hydraulic sciences and engineering.

6. Course Goals: By the end of this course, the students will be able to …

- Know, comprehend, apply and analyze fundamental hydrologic and hydraulic measurement techniques.
- Apply field measurement techniques to collect and analyze hydrologic and hydraulic data.
- Conduct sampling and testing of surface water, groundwater and sediments.
- Conduct field reconnaissance work for research and applied engineering applications.
- Analyze and interpret hydrologic and hydraulic field data.
- Report and present data analysis and results.

7. Requirements:

- Compulsory fieldwork attendance.
- Intensive fieldwork participation.
- The use of personal computers is required. Written reports, graphs, diagrams, and drawings are to be made through personal computers using word processors, electronic spreadsheets, and presentation graphics.
- Turn in the homework, special problems and project, and reports on time.
- Follow safety and security procedures.
- Keep all notes in an accessible field notebook.
- **E-mail:** All students must have an e-mail account to receive important course notes, updates, and changes. The e-mail address will be provided to the instructor, via e-mail. Students are responsible ton check for material sent through e-mail.

8. Laboratory/Field Work (If applicable):

No laboratory work. See attached schedule for fieldwork.

9. Department/Campus Policies:

9a. **Class attendance:** Class and fieldwork attendance is compulsory. The University of Puerto Rico, Mayagüez Campus, reserves the right to deal at any time with individual cases of non-attendance. Professors are expected to record the absences of their students. Frequent absences affect the final grade, and may even result in total loss of credits. Arranging to make up work missed because of legitimate class absence is the responsibility of the student (see Bulletin of Information Undergraduate Studies, 2002-2003).

9b. **Absence from field work:** Students are required to attend field work. If a student is absent, he or she will receive a grade of zero in the fieldwork component.

9c. **Final examinations:** Final written examinations must be given in all courses unless, in the judgment of the Dean, the nature of the subject makes it impracticable. Final examinations scheduled by arrangements must be given during the examination period prescribed in the Academic Calendar, including Saturdays. (see Bulletin of Information Undergraduate Studies, 2002-2003).

9d. **Partial withdrawals:** A student may withdraw from individual courses at any time during the term, but before the deadline established in the University Academic Calendar. (see Bulletin of Information Undergraduate Studies, 2002-2003).

9e. **Complete withdrawals:** A student may completely withdraw from the University of Puerto Rico, Mayagüez Campus, at any time up to the last day of classes. (see Bulletin of Information Undergraduate Studies, 2002-2003).

9f. **Disabilities:** All the reasonable accommodations according to the Americans with Disability Act (ADA) Law will be coordinated with the Dean of Students and in accordance with the particular needs of the student.

9g. **Ethics:** Any academic fraud is subject to the disciplinary sanctions described in article 14 and 16 of the revised General Student Bylaws of the University of Puerto Rico contained in Certification 018-1997-98 of the Board of Trustees. The professor will follow the norms established in articles 1-5 of the Bylaws.

10. General Topics:

Lecture	Topic	Reading Material
1 (8/13)	Introduction & Safety Issues	Handout, References
2 (8/19)	Climatic Variable Analysis	Handout, References
3 (8/26)	Evaporation and Evapotranspiration	Handout, References
4 (9/2)	Infiltration	Handout, References
5 (9/9)	SW Hydraulic Measurement	Handout, References
6 (9/16)	Sediment Transport	Handout, References
7 (9/30)	Pumping and Specific Capacity Test	Handout, References
8 (10/21)	Aquifer Test and Groundwater Sampling	Handout, References

FIELDWORK SCHEDULE

Laboratory	Topic	Report Due Date	Reading Material
1 (8/20, 8/27)	Climatic Variable Analysis	9/2	Handouts, References
2 (9/3)	Evaporation and Evapotranspiration	11/18	Handouts, References
3 (9/10)	Infiltration	9/16	Handouts, References
4 (9/17, 9/24)	SW Hydraulic Measurement	10/7	Handouts, References
5 (9/17, 9/24)	Sediment Transport	10/14	Handouts, References
6 (10/1)	Pumping and Specific Capacity Test	10/21	Handouts, References
7 (10/22)	Aquifer Test and Groundwater Sampling	11/4	Handouts, References

University of Puerto Rico
Mayagüez Campus
College of Engineering

B. Instructor Information Sheet

1. General Information:

Instructor: Dr. Walter Silva
Title: Professor
Office: Stefani 110A
Phone: 832-4040 ext. 3494

Office Hours: MWF 10:30-12:30
(Other hours by Appointment)
Co-Instructors: Dr. Jorge Rivera-Santos, Raul Zapata, Dr. Ingrid Padilla

2. Course Description:

Course Number: INCI 6116
Course Title: Hydrologic and Hydraulic Field Measurement Methods
See element number 2 (Course Description) of Course Syllabus Section.

3. Purpose:

See element number 5 (Purpose) of Course Syllabus Section.

4. Course Goals:

See element number 6 (Course Goals) of Course Syllabus Section.

5. Instructional Strategy:

- Conference
- Fieldwork
- Sampling
- Testing
- Oral/written Reports

6. Evaluation/Grade Reporting:

Grades will be based on attendance, fieldwork participation, written reports, and oral presentations. Special problems and short projects may also be given at the instructor's discretion. The weighting will be as follows: Attendance and fieldwork participation (45%), written reports (45%), and oral presentation (10%).

In general, 90-100% = A, 80-89% = B, 70-79% = C, 60-69% = D, <60% = F

9. Deadlines for Assignments (Optional):

The instructor will give deadlines for each activity. All work must be turned during class, on the day is due. After that, 5 points will be taken off per day for 5 days. No assignment will be accepted after 5 days of its due date.

10. Student Assistance (If applicable):

11. Attendance and Behavior:

- Attendance to class and fieldwork is mandatory. If you miss a class, you need to present a written excuse to the professor. Missing class more than 3 times may be grounds to lower your final grade at the professor's discretion. After 3, each absence will result in 1 point off the final class grade.
- Students are required to attend all fieldwork. If you miss <u>a</u> (one) field activity for a justifiable reason acceptable to the professor, you need a written excuse. Otherwise, a grade of zero will be given to the missed fieldwork component. Missing more than one field activity you will be given the opportunity to withdraw from the class or you will receive an F".
- Students are encouraged to share, discuss, and interact; however, all graded work must be done independently, except as noted by instructor. <u>Plagiarism</u>: the penalty for academic dishonesty is failure on the piece of work.
- **<u>Use of beepers and cellular phones is prohibited during class hours</u>**

12. Instructor Responsibilities (If applicable):

- Help to obtain and prepare samples, plan fieldwork standard procedures, assist in fieldwork preparation, provide tutorial support to students.
- Preliminary schedule will be announced at the beginning of the semester, but the dates and times are subjected to changes. If rescheduling is necessary, the new dates and times will be announced with at least one week in advance.

13. Course Outline And Schedule:

a) **Course Outline.** See element 10 (General Topics) of course Syllabus for topics. General topics to be covered follow in approximate order. The instructor may, if necessary, change the order of the topics.

b) **Approximate Schedule.** Approximate schedule for reports and presentation follows. The instructor may, if necessary, change the scheduled dates in coordination with the students.

i. Written Report- See element 10 (General Topics) of course Syllabus.
ii. Oral Presentation – November 26, 2003; December 3, 2003.

14. Additional References:

i. Biedernharn, Elliot and Watson, *The West Stream Investigation and Streambank Stabilization Handbook*, U.S. Army Corps of Engineers, 1997.
ii. Dahmen and Hall, *Screening of Hydrologic Data*, ILRI Publication No. 49, 1990.
iii. Dawson, K.J. and Istok, J.D., *Aquifer Testing: Design and Analysis of Pumping and Slug Tests*, Lewis Publishers, 1991.
iv. Driscoll, F.G., *Groundwater and Wells*, 2nd ed., Johnson Division, 1986.
v. Ferguson, *Stormwater Infiltration*, Lewis Publishers, 1994.
vi. Fetter, C. W., *Applied Hydrogeology*, 4th ed., Prentice Hall, 2001.
vii. Goldman, Jackson, and Burszdynsky, *Erosion and Sediment Control Handbook*, McGraw Hill, 1986.
viii. Heath, R., *Basic Ground-Water Hydrology*, U.S. Geological Survey Water-Supply Paper 2220, 1989.
ix. Kasenow, M., *Applied Ground-water Hydrology and Well Hydraulics*, Water Resources Publications, LLC, 2000.
x. Lal, R., *Soil Erosion Research Methods*, Soil and Water Conservation Society, 1994.
xi. Meadows and Walski, *Computer Applications in Hydraulic Engineering*, Haestad Methods, 2002.
xii. Roberson,,J.A., J. Cassidy, and Chaudhry, *Hydraulic Engineering*, 2nd Ed., John Wiley, 1997.
xiii. U.S. Army Corps of Engineers, *Hydrographic Surveying*, EM 1110-2-1003, 1991.
xiv. Yang, C.T., *Sediment Transport Theory and Practice*, McGraw Hill, 1996.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	7	0	0	0	7
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	11	0	0	0	11

Notable Awards and Achievements

The director of the PRWRERI was appointed member of the interagency committee for the development of the Integrated Management Plan for Water Resources of Puerto Rico by the Secretary of the Department of Natural and Environmental Resources of Puerto Rico.

No awards were received during this year.

Publications from Prior Projects