Puerto Rico Water Resources Research Institute
Annual Technical Report
FY 2005

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 Rico 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 Rico 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 electronic newsletter are used by the Institute to keep the water resources community and general public informed about advances in research. Approximately once every two to three years, the Institute organizes major conferences on water-related research in Puerto Rico and the Caribbean, in collaboration with other Water Resources Research Institutes, government agencies, and 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 by 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 FY2005 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. The use of GIS techniques allowed the development of a tool to identified areas, within the watershed, with high probability of being polluted with Fecal Coliform bacteria. This project was started in FY2004 and ended in December, 2005.

2. OPERATIONAL HYDRAULIC MODEL FOR THE SOUTH WESTERN REGION OF PUERTORICO (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 allow the analysis of alternatives and produce information to take decision to solve these problems.

The Puerto Rico Aqueduct and Sewerage Authority and the Municipality of Mayaguez joined effort to sponsor the construction of the first operation model for the Southwestern Region of Puerto Rico. This project is now approaching the end of its first year and should be finished by December 2006. Two complex pipe network systems are now totally digitized, including pipes down to 2 inches in diameter; corresponding to Miradero and Ponce de Leon Water Treatment Plant systems. The models will be the first of this nature in Puerto Rico, with application for operational purposes. The tool will be helpful for decision making processes, including system expansion, rehabilitation and replacement of old pipes.

The project success has been evident in several areas such as:

- Creation of a methodology for demand estimation based on PRASAs metered water measurements and information systems, which is unique for Puerto Rico.

- Total digitalization of PRASAs old pipe distribution system drawings, upgrade of pipe network plans to incorporate the newest urban developments and as-build details.

- Digitalization of meter reading routes.

- Creation of a database with the characteristics of the hydraulic system such as pipe diameter, age and material, pump systems capacity, tanks capacity and water level oscillations, etc.

The models are under calibration and the project is a 75% completed. This project also provides training of civil engineering student in state-of-the-art hydraulic network models, geographic information systems and, use of field measurement equipment required for calibration of pressure pipe networks.

3. COLLOQUIUM ON WATER QUALITY MONITORING AND TESTING IN LATIN AMERICA AND THE CARIBBEAN (sponsored by USEPA, UPRM, and PRWRERI)

The U.S. Environmental Protection Agency (EPA) and the University of Puerto Rico (UPR), with cooperation from the Pan American Health Organization (PAHO), hosted the Colloquium on Water Quality Monitoring and Testing in Latin America and the Caribbean in October 2005. Thirty-nine countries sent representatives to the meeting, which was held in San Juan, Puerto Rico. The meeting provided a forum for information exchange among USEPA, UPRM, PAHO and International participants having an interest in all aspects of water quality.

The Colloquium was convened to bring nations of the Caribbean and Latin America together to identify current and future needs to improve water quality monitoring, control and data evaluation. The Colloquium focused on water quality issues in Latin America and the Caribbean, and the creation of a Center of Excellence for Water Quality in Puerto Rico.

Keynote speakers were

- Jorge I. Vélez-Arocho, Chancellor, University of Puerto Rico at Mayagüez. - Dr. Velez-Arocho focused on water quality issues, specifically preservation and management of water resources. He also discussed the need to improve management of wastes, much of which is discharged to rivers and lakes, and the need to address the issue of diminishing water supply.

- Javier Vélez-Arocho, Secretary, Department of Natural and Environmental Resources, Puerto Rico. - Secretary Vélez-Arocho discussed Puerto Ricos efforts in the area of water research in developing water basins and in the reforestation of Puerto Rico.

- Carl-Axel Soderberg, Director, Caribbean Environmental Protection Division, U.S. Environmental Protection Agency. - Mr. Soderberg discussed the availability of water resources in Latin America and the Caribbean. He pointed out that many countries do not have appropriate water resources and others are water-stressed because water resources are not located near high population density centers. He summarized his presentation by pointing out that if we do not act soon, it will cost more in the future and result in even greater health and ecological effects than are occurring now.

- Peter Toft, Pan American Health Organization. - Peter Toft reviewed the changes that have been ongoing at PAHO in the last two years. Mr. Toft also spoke about the importance of laboratory accreditation and proficiency testing and the benefits that accrue from these activities, such as data that might be used for making meaningful judgments about health risks from pollutants in the environment.

Nine technical and management sessions were held, which addressed various issues of interest to scientists and managers of all nations attending the Colloquium. The majority of the issues addressed by participant presentations centered on water quality problems in Latin America and the Caribbean. Other water quality aspects included traditional and advanced analytical methods for monitoring recreational and drinking water, guidelines for tropical recreational waters, quality control of drinking water and legislation and regulations related to water quality. Session presentations also addressed the issues of satellite imaging and remote sensing as they apply to water quality, and laboratory issues, such as quality control, capacity, certification and oversight programs.

A survey regarding the major needs with respect to water quality and water quality testing was administered prior to the colloquium to all international participants. The results of the survey were reviewed and the non-prioritized top eleven needs of participating countries were determined as follows:

- Training for laboratory managers

- Development of biological indicators

- Monitoring surface water quality

- Dealing with increases in waterborne pathogens

- Integrated water management

- Training for laboratory analysts

- Sanitation and drinking water availability for cities

- Low-tech solutions for on-site delivery of safe drinking water

- Quality assurance/laboratory certification auditor

- Waste water discharges

- Monitoring drinking water safety

Break-out groups, representing various regions of Latin America and the Caribbean prioritized the most relevant issues during the colloquium. The issues identified by these groups were

- Delivery of safe water

- Availability and quality of drinking water for cities and integrated

- Monitoring surface water quality

- Training for laboratory managers

- Training, re-training, and recruitment of laboratory staff management

The needs and issues discussed by the break-out groups at the Colloquium reflected in part the priority needs that resulted from the pre-Colloquium survey of meeting participants.

The outcome of the Colloquium will be based on the joint efforts of the University of Puerto Rico, the U.S. Environmental Protection Agency, and the Pan American Health Organization to meet some of the needs suggested by the meeting participants. It is anticipated that training in water assay methods or laboratory accreditation training will be initiated in the near future.

Research Program

Two projects were funded under the 104b program during FY2005. One of these projects was completed within the reporting period and the other was given a non-cost time extension until December, 2006. The completion report for a third project, funded during FY2003 and to which a non-cost time extension had been given, is presented in this report. The next section presents the final report for the FY2005 completed project, final report for the FY2003 completed project, and the progress reports (four quarterly reports) for the time extended FY2005 project.

Monitoring Nutrients Content in the San Juan Bay Estuary using Hyperspectral Remote Sensing

Basic Information

Title:	Monitoring Nutrients Content in the San Juan Bay Estuary using Hyperspectral Remote Sensing
Project Number:	2005PR20B
Start Date:	3/1/2005
End Date:	12/31/2006
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	Nutrients, Nitrate Contamination, Non Point Pollution
Descriptors:	
Principal Investigators:	Fernando Gilbes

Publication

This project was granted a non-cost time extension until December, 2006. The nature of the project has contributed to the delays since it depends on good weather conditions (cloudless days) the same time the satellite passes over the study area. Details are given in the quarterly progress reports include herein.

PUERTO RICO WATER RESOURCES AND ENVIRONMENTAL RESEARCH INSTITUTE

104B SECTION RESEARCH PROGRAM

QUARTERLY PROGRESS REPORT

Date of the report: June 3, 2005

Project Title: Monitoring Nutrients Content in the San Juan Bay Estuary using Hyperspectral Remote Sensing.

Name of Contact (PI): Dr. Fernando Gilbes Santaella

Telephone: (787) 832-4040 X-3000 **Fax:** (787) 265-3845
email: gilbes@cacicque.uprm.edu

Names of Co-Pi's: N/A

Percentage of Work Completed in this quarter: 10%

Accumulative Percentage of Work Completed (%): 15%

Completion Date: February 28, 2006

Project Status: _ Schedule _ Suspended X Delayed _ Cancelled _ Completed

Activities Progress: (According to Work Schedule submitted with application)

Task #	Major Activity	Date Started	% Completed	Estimated Date of Completion	Date Completed	Dependant on Task(s):
1	Visit to the USGS and San Juan Estuarine Bay Program Facilities to obtain physical and sampling data from San Juan Bay lagoons.	April 12, 2005	100	April 15, 2005	April 15,2005	N/A
2	Field trip to the study site for identification of sampling	June 6, 2005	N/A	June 6, 2005	N/A	N/A

	locations in the San Juan Bay Estuary system; radiance measurements with the GER-1500 spectroradiometer. Sampling locations will be identified using Geographical Positioning System.					
3	Place order for hyperspectral images of Hyperion sensor.	May 17, 2005	100	1st week of May	May 17, 2005	N/A
4	June sampling and image collection for selected lagoons.	N/A	N/A	N/A	N/A	N/A
5	Purchasing of personal computer and ENVI image processing software.	May 10, 2005	25	N/A	N/A	N/A
6	Evaluation and interpretation of June field sampling and image data.	N/A	N/A	N/A	N/A	N/A
7	Preparation of nitrates and total phosphorus concentrations profiles using water quality model.	N/A	N/A	N/A	N/A	N/A
8	Image processing, including atmospheric correction and classification.	N/A	N/A	N/A	N/A	N/A
9	July sampling and image collection for selected lagoons.	N/A	N/A	N/A	N/A	N/A
10	Evaluation and interpretation of July field sampling and image data.	N/A	N/A	N/A	N/A	N/A
11	Preparation of nitrates and total phosphorus concentrations profiles using water quality model.	N/A	N/A	N/A	N/A	N/A
12	Image processing, including atmospheric correction and classification.	N/A	N/A	N/A	N/A	N/A
13	Preparation of nitrates and total phosphorus spectral profiles and validation with results of water quality model; correlation analysis for water quality and image data.	N/A	N/A	N/A	N/A	N/A
14	September sampling and image collection for selected lagoons.	N/A	N/A	N/A	N/A	N/A
15	Evaluation and interpretation of sampling and image data.	N/A	N/A	N/A	N/A	N/A

16	Preparation of nitrates and total phosphorus concentration profiles using water quality model.	N/A	N/A	N/A	N/A	N/A
17	Image processing, including atmospheric correction and classification.	N/A	N/A	N/A	N/A	N/A
18	Preparation of nitrates and total phosphorus spectral profiles and validation with results of water quality model; correlation analysis for water quality and image data.	N/A	N/A	N/A	N/A	N/A
19	Preparation of dissertation report.	N/A	N/A	N/A	N/A	N/A
20	Submit dissertation to Graduate Committee advisor and Principal Investigator.	N/A	N/A	N/A	N/A	N/A
21	Corrections to dissertation.	N/A	N/A	N/A	N/A	N/A
22	Defense of dissertation.	N/A	N/A	N/A	N/A	N/A

Summary of Progress on Project this Quarter:

During April important data were obtained from the United States Geological Survey, collected in the San Juan Bay Estuary System in 1993. Such information provides data related with water quality, lagoons location, vegetation characteristics, climate, and other valuable parameters. During May 2005, three (3) purchase orders were prepared for the Hyperion hyperspectral images to be used during the project. Costs for the personal computer and image processing software have already been assessed and a purchase order will be submitted shortly. Quotations and arrangements have already been made with a private environmental laboratory to provide sampling analyses and results. The first sampling survey was programmed for May 16 of 2005; however, it had to be postponed due to bad weather. It was reprogrammed for June 6, 2005 when four (4) samples will be obtained from the San José lagoon and be analyzed for nitrites, nitrates, total nitrates + nitrates, and total phosphorus. Also, reflectance data and geographic position will be collected for the sampling locations on that date.

Problems Encountered and/or Assistance Needed:

There have been some delays in the field work due to problems out of our control. Boating services for the field work in the San José lagoon was a difficult task due to the lack of local companies that provide such service. After a large effort the services were arranged with a private boat owner that will charge per trip. Service agreements with the laboratory were delayed due to logistic problems related with the university's payment procedures.

Certifications:

As the Principal Investigator, I certify that the information contained within this quarterly report accurately reflects the status of this project.

June 3, 2005

Project Investigator Signature & Title **Date**

PUERTO RICO WATER RESOURCES AND ENVIRONMENTAL RESEARCH INSTITUTE

104B SECTION RESEARCH PROGRAM

QUARTERLY PROGRESS REPORT

Date of the report: October 15, 2005

Project Title: Monitoring Nutrients Content in the San Juan Bay Estuary using Hyperspectral Remote Sensing.

Name of Contact (PI): Dr. Fernando Gilbes-Santaella

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Email: gilbes@cacique.uprm.edu

Names of Co-Pi's: N/A

Percentage of Work Completed in this quarter: 15%

Accumulative Percentage of Work Completed (%): 25%

Completion Date: February 28, 2006

Project Status: _ Schedule _ Suspended X Delayed _ Cancelled _ Completed

Activities Progress: (According to Work Schedule submitted with application)

Task #	Major Activity	Date Started	% Completed	Estimated Date of Completion	Date Completed	Dependant on Task(s):
1	Visit to the USGS and San Juan Estuarine Bay Program Facilities to obtain physical and sampling data from San Juan Bay lagoons.	April 12, 2005	100	April 15, 2005	April 15,2005	N/A
2	Identification of sampling stations in San Jose lagoon; radiance measurements with spectroradiometer. Sampling locations will be tied with Geographical Positioning System in both the field data and Hyperion	June 6, 2005	50	June 6, 2005	N/A	N/A

	images.					
3	Purchase of hyperspectral images (Hyperion).	May 10, 2005	100	1st week of May	September 23, 2005 (1st image)	N/A
4	First visit to the San José lagoon and collect samples for water quality and radiance measurements from a grid of several stations.	August 7, 2005	100	August 7, 2005	August 7, 2005	N/A
4a	Water samples analyzed for Nitrates + Nitrites and Total Phosphorus.	August 8, 2005	100	August 10, 2005	August 10, 2005	4
5	Purchasing of personal computer and image processing software ENVI.	May 10, 2005	25	N/A	N/A	N/A
6	Processing, analysis, and interpretation of collected data during the first sampling.	N/A	N/A	N/A	N/A	N/A
7	Preparation of nitrates and total phosphorus concentrations profiles using water quality model.	N/A	N/A	N/A	N/A	N/A
8	Image classification and atmospheric correction.	N/A	N/A	N/A	N/A	N/A
9	Second field sampling and image collection in San Jose lagoon.	N/A	N/A	N/A	N/A	N/A
10	Processing, analysis, and interpretation of collected data during the second sampling.	N/A	N/A	N/A	N/A	N/A
11	Preparation of nitrates and total phosphorus concentrations profiles using water quality model.	N/A	N/A	N/A	N/A	N/A
12	Image classification and atmospheric correction.	N/A	N/A	N/A	N/A	N/A
13	Preparation of nitrates and total phosphorus spectral profiles and validation with results of water quality model; correlation analysis for water quality and image data.	N/A	N/A	N/A	N/A	N/A
14	Third field sampling and image collection in San	N/A	N/A	N/A	N/A	N/A

	Jose lagoon.					
15	Processing, analysis, and interpretation of collected data during the third sampling.	N/A	N/A	N/A	N/A	N/A
16	Preparation of nitrates and total phosphorus concentration profiles using water quality model.	N/A	N/A	N/A	N/A	N/A
17	Image classification and atmospheric correction.	N/A	N/A	N/A	N/A	N/A
18	Preparation of nitrates and total phosphorus spectral profiles and validation with results of water quality model; correlation analysis for water quality and image data.	N/A	N/A	N/A	N/A	N/A
19	Preparation of draft dissertation report.	N/A	N/A	N/A	N/A	N/A
20	Submittal of draft report to Graduate Counselor and Principal Investigator.	N/A	N/A	N/A	N/A	N/A
21	Corrections to draft dissertation report.	N/A	N/A	N/A	N/A	N/A
22	Defense of project dissertation.	N/A	N/A	N/A	N/A	N/A

Summary of activities during this quarter:

The project activities have been delayed due to cloud cover. Hyperion image collection requires days with clear sky in order to perform a good validation. Since we are in the wet season of Puerto Rico it has been difficult to obtain a clear image. The USGS collected the first Hyperion image during June 22, 2005 (Figure 1a). Field data was not collected during that day because the field radiometer was not working properly. A second Hyperion image was collected during August 7, 2005 (Figure 1b). Field data was collected that day in 38 stations of San Jose Lagoon (Figure 2). Nutrients concentration was measured and the results are shown in Figure 3. In September the USGS changed the frequency of the satellite overpass on the study region, which significantly reduced all imaging activities until October. The spectral data to be obtained from the second image (which was sufficiently clear for the sampling area) will be used to compare the spectral and sampling data to be obtained from the selected image. At the time of the preparation of this report we are still waiting for the USGS to provide us with the next satellite overpass date in order to perform the second field sampling campaign.

The quotations for the personal computer and the software ENVI were submitted to the Puerto Rico Water Resources and Environmental Research Institute for its purchase.

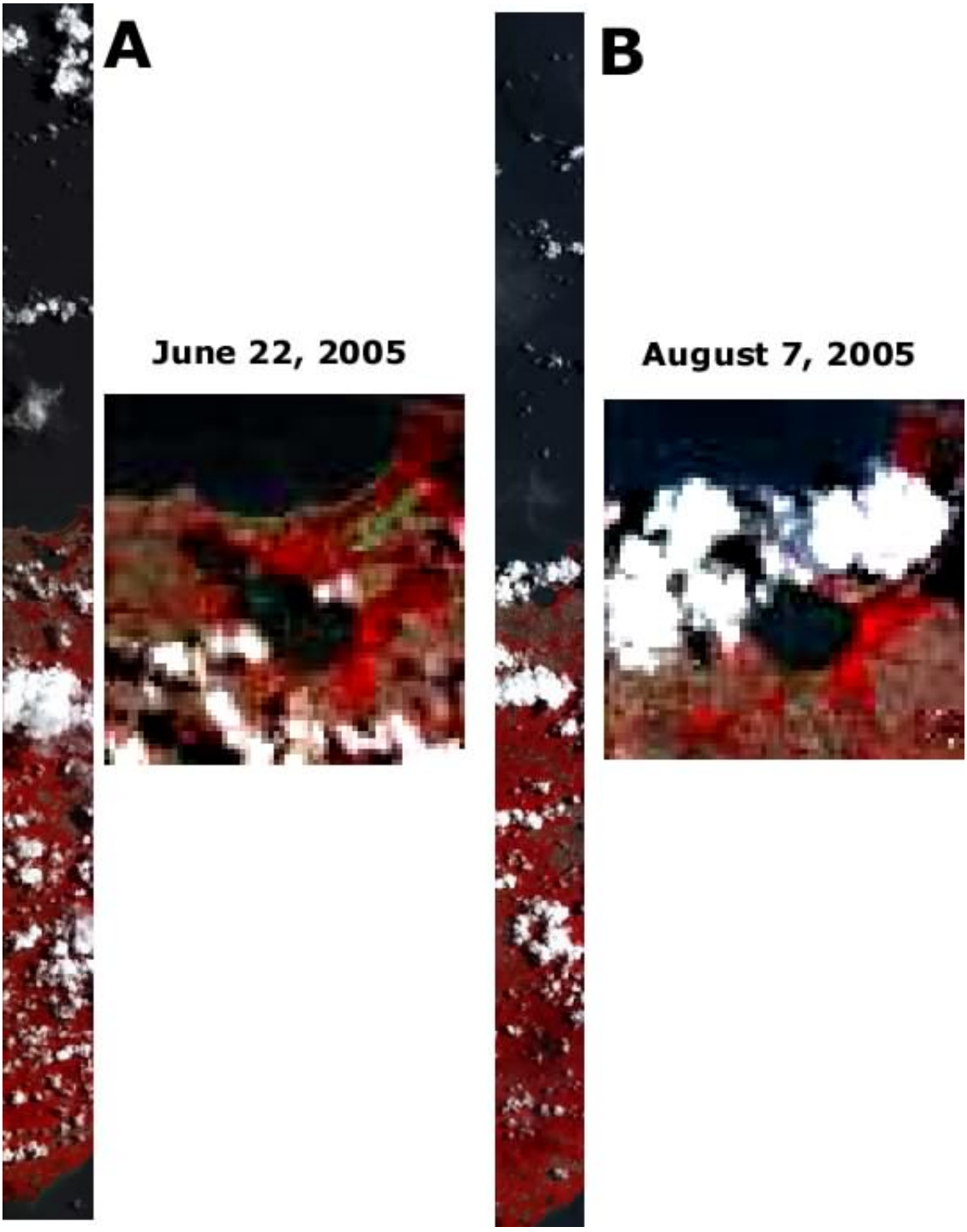

Figure 1: Hyperion Images collected over the San Jose Lagoon.

Figure 2: Study area and sampling stations in San Jose Lagoon.

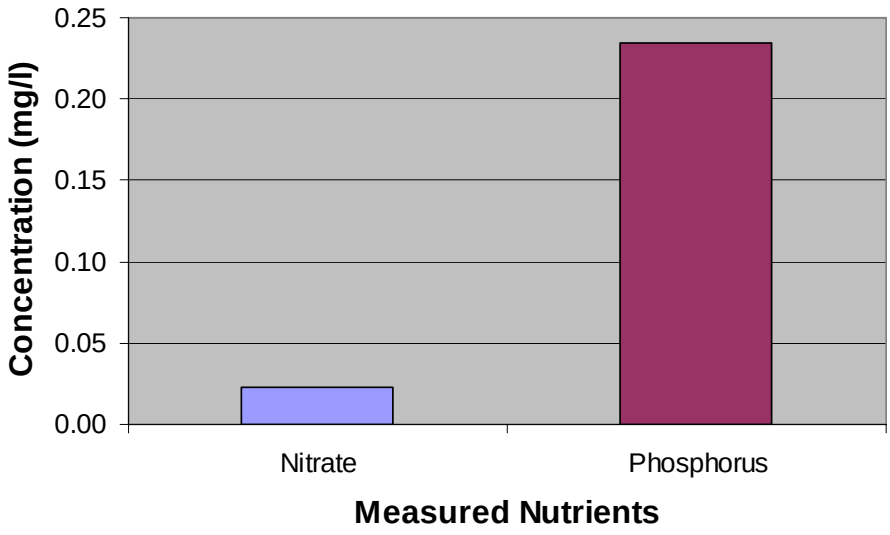

Figure 3: Mean Concentration of nutrients measured in 38 stations.

Problems Encountered and/or Assistance Needed:

1. The field spectroradiometer GER-1500 was not working properly and we need to send it to the factory in New York for checkout, reparation, and calibration. This problem delayed the field activities for about a month.

2. Large cloud cover over the study site required that three passes of Hyperion were collected in order to select the clearest one. This situation has not allowed us to start the image processing and validation procedures.

3. The frequency of satellite overpass was significantly reduced by the USGS due the change in the Earth's orbit trajectory during the month of September, which required that all imaging activities be delayed until October.

Certifications:

As the Principal Investigator, I certify that the information contained within this quarterly report accurately reflects the status of this project.

Principal Investigator October 15, 2005

Project Investigator Signature & Title **Date**

PUERTO RICO WATER RESOURCES AND ENVIRONMENTAL RESEARCH INSTITUTE

104B SECTION RESEARCH PROGRAM

QUARTERLY PROGRESS REPORT

Date of the report: December 1, 2005

Project Title: Monitoring Nutrients Content in the San Juan Bay Estuary using Hyperspectral Remote Sensing.

Name of Contact (PI): Dr. Fernando Gilbes

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Names of Co-Pi's: N/A

Percentage of Work Completed in this quarter: 25%

Accumulative Percentage of Work Completed (%): 30%

Completion Date: February 28, 2006

Project Status: _ Schedule _ Suspended X Delayed _ Cancelled _ Completed

Activities Progress: (According to Work Schedule submitted with application)

Task #	Major Activity	Date Started	% Completed	Estimated Date of Completion	Date Completed	Dependant on Task(s):
1	Visit to the USGS and San Juan Estuarine Bay Program Facilities to obtain physical and sampling data from San Juan Bay lagoons	April 12, 2005	100	April 15, 2005	April 15,2005	N/A
2	Visit to site for identification of sampling locations for at least 1 lagoon of the San Juan Bay Estuary system; radiance measurements with spectro radiometer. Sampling	June 6, 2005	50	June 6, 2005	N/A	N/A

	locations will be tied with Geographical Positioning System in both the field and imaging sensor.					
3	Purchase of hyperspectral images	May 10, 2005	100	1st week of May	September 23, 2005 (1st image)	N/A
4	Visit to the San José lagoon site and obtained first round of water quality samples and radiance measurements from a defined grid in the lagoon.	August 7, 2005	100	January10. 2006	Pending	N/A
4a	Water samples analyzed for Nitrates + Nitrites and Total Phosphorus	August 8, 2005	100	August 10, 2005	August 10, 2005	4
5	Purchasing of personal computer and image processing software	May 10, 2005	25	N/A	N/A	N/A
6	Evaluation and interpretation of May sampling and image data	N/A	N/A	N/A	N/A	N/A
7	Preparation of nitrates and total phosphorus concentrations profiles using water quality model	N/A	N/A	N/A	N/A	N/A
8	Image classification, atmospheric correction	N/A	N/A	N/A	N/A	N/A
9	July sampling and image event for lagoon locations	N/A	N/A	N/A	N/A	N/A
10	Evaluation and interpretation of July sampling and image data	N/A	N/A	N/A	N/A	N/A
11	Preparation of nitrates and total phosphorus concentrations profiles using water quality model	N/A	N/A	N/A	N/A	N/A
12	Image classification, atmospheric correction	N/A	N/A	N/A	N/A	N/A
13	Preparation of nitrates and total phosphorus spectral profiles and validation with results of water quality model; correlation analysis for water quality and image data	N/A	N/A	N/A	N/A	N/A
14	November sampling and	November 6,	100	November 06,	November 06,	N/A

	image event for lagoon locations	2005		2005	2005	
15	Evaluation and interpretation of sampling and image data	N/A	N/A	N/A	N/A	N/A
16	Preparation of nitrates and total phosphorus concentration profiles using water quality model	N/A	N/A	N/A	N/A	N/A
17	Image classification, atmospheric correction	N/A	N/A	N/A	N/A	N/A
18	Preparation of nitrates and total phosphorus spectral profiles and validation with results of water quality model; correlation analysis for water quality and image data	N/A	N/A	N/A	N/A	N/A
19	Preparation of draft dissertation report	N/A	N/A	N/A	N/A	N/A
20	Submittal of draft report to Graduate Counselor and Principal Investigator	N/A	N/A	N/A	N/A	N/A
21	Corrections to draft dissertation report	N/A	N/A	N/A	N/A	N/A
22	Defense of project dissertation	N/A	N/A	N/A	N/A	N/A

Summary of Progress on Project this Quarter:

Delays still prevail in the project due to changes in the United States Geological Survey Data Acquisition Request (DAR) procedures. The U.S.G.S informed that all DARs must be re-submitted for all images to be obtained after October, 2005 after new administrative procedures issued by the government agency. Prices for all images were modified, which required from the University of Puerto Rico the preparation of new purchase orders for the new prices announced. Internal university administrative procedures further delayed the progress of the research activities.

Problems Encountered and/or Assistance Needed:

See narrative report above.

Certifications:

As the Principal Investigator, I certify that the information contained within this quarterly report accurately reflects the status of this project.

Principal Investigator — October 15, 2005

Project Investigator Signature & Title — **Date**

PUERTO RICO WATER RESOURCES AND ENVIRONMENTAL RESEARCH INSTITUTE

104B SECTION RESEARCH PROGRAM

QUARTERLY PROGRESS REPORT

Date of the report: June 1, 2006

Project Title: Monitoring Nutrients Content in the San Juan Bay Estuary using Hyper Spectral Remote Sensing.

Name of Contact (PI): Dr. Fernando Gilbes

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Names of Co-Pi's: N/A

Percentage of Work Completed in this quarter: 5 %

Accumulative Percentage of Work Completed (%): 35%

Completion Date: December 31, 2006

Project Status: _ Schedule _ Suspended X Delayed _ Cancelled _ Completed

Activities Progress: (According to Work Schedule submitted with application)

Task #	Major Activity	Date Started	% Completed	Estimated Date of Completion	Date Completed	Dependant on Task(s):
1	Visit to the USGS and San Juan Estuarine Bay Program Facilities to obtain physical and sampling data from San Juan Bay lagoons	April 12, 2005	100	April 15, 2005	April 15,2005	N/A
2	Visit to site for identification of sampling locations for at least 1 lagoon of the San Juan Bay Estuary system; radiance measurements with spectro radiometer. Sampling locations will be tied with GPS in both	June 6, 2005	50	June 6, 2005	N/A	N/A

	the field and image.					
3	Purchase of hyperspectral images	May 10, 2005	100	1st week of May	September 23, 2005 (1st image)	N/A
4	Visit to the San José lagoon and obtained first round of water quality samples and radiance measurements from a defined grid.	August 7, 2005	100	January 10, 2006	Pending	N/A
4a	Water samples analyzed for Nitrates + Nitrites and Total Phosphorus	August 8, 2005	100	August 10, 2005	August 10, 2005	4
5	Purchasing of personal computer and image processing software	March 6, 2006	100	March 6, 2006	March 6, 2006	N/A
6	Evaluation and interpretation of August sampling and image data	August 17, 2005	50	June 22, 2006	N/A	4
7	Preparation of nitrates and total phosphorus concentrations profiles using water quality mod.	N/A	N/A	N/A	N/A	N/A
8	Image classification, atmospheric correction	June 15, 2006	50	June 22, 2006	N/A	6
14	Nov. 2005 sampling and image event for lagoon locations	November 6, 2005	100	November 06, 2005	November 06, 2005	N/A
15	Evaluation and interpretation of sampling and image data	November 11, 2005	50	November 11, 2006	N/A	N/A
16	Preparation of nitrates and total phosphorus concentration profiles using water quality model	N/A	N/A	N/A	N/A	N/A
17	Image classification, atmospheric correction	N/A	N/A	N/A	N/A	N/A
18	Preparation of nitrates and total phosphorus spectral profiles and validation with results of water quality model; correlation analysis for water quality and image data	N/A	N/A	N/A	N/A	N/A
19	Feb. 2006 sampling and	February 24,	100	February 24,	February 24,	N/A

	image event for lagoon locations	2006		2006	2006	
20	Evaluation and interpretation of sampling and image data	February 28, 2006	50	June 22, 2006	N/A	N/A
21	Preparation of nitrates and total phosphorus concentration profiles using water quality mod.	N/A	N/A	N/A	N/A	N/A
22	Image classification, atmospheric correction	N/A	N/A	N/A	N/A	N/A
23	Preparation of nitrates and total phosphorus spectral profiles and validation with results of water quality model; correlation analysis for water quality and image data	N/A	N/A	N/A	N/A	N/A
19	June, 2006 sampling and image event for lagoon locations	June 3, 2006	100	June 3, 2006	June 3, 2006	N/A
20	Evaluation and interpretation of sampling and image data	N/A	N/A	N/A	N/A	N/A
21	Preparation of nitrates and total phosphorus concentration profiles using water quality model	N/A	N/A	N/A	N/A	N/A
22	Image classification, atmospheric correction	N/A	N/A	N/A	N/A	N/A
23	Preparation of nitrates and total phosphorus spectral profiles and validation with results of water quality model; correlation analysis for water quality and image data	N/A	N/A	N/A	N/A	N/A
24	Preparation of draft dissertation report	N/A	N/A	N/A	N/A	N/A
25	Submittal of draft report to Graduate Counselor and Principal Investigator	N/A	N/A	N/A	N/A	N/A
26	Corrections to draft	N/A	N/A	N/A	N/A	N/A

	dissertation report					
27	Defense of project dissertation	N/A	N/A	N/A	N/A	N/A

Summary of Progress on Project this Quarter:

Additional field samplings were carried out during days of satellite overpasses. The field reflectance measurements and the nutrients are being processed and analyzed in order to compare them with the Hyperion images. The Hyperion image collected during February 24 of 2006 is being received and we are now performing the atmospheric correction using the software called Atmospheric COrrection Now (ACORN). This initial step will produce a corrected image with reflectance values that will be compared with the field data. The same image has been explored using ENVI.

Hyperion image collected during February 24, 2004. Field data was collected this day.

Problems Encountered and/or Assistance Needed:

Delays still prevail in the project due to scheduling problems with the EO-1 satellite and repeated passes due to excessive cloudiness. The USGS has reduced the passes frequency for the Caribbean without notice, even when the Data Acquisition Requests (DAR) were submitted in a timely manner.

Certifications:

As the Principal Investigator, I certify that the information contained within this quarterly report accurately reflects the status of this project.

Associate Professor June 20, 2006

Project Investigator Signature & Title **Date**

Removal of Inorganic, Organic and Antimicrobials Contaminants from Aqueous Solutions by Waste Tire Crumb Rubber

Basic Information

Title:	Removal of Inorganic, Organic and Antimicrobials Contaminants from Aqueous Solutions by Waste Tire Crumb Rubber
Project Number:	2005PR21B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Treatment, Water Quality, Toxic Substances
Descriptors:	
Principal Investigators:	Oscar J Perales-Perez, Marco A. Arocha, Felix Roman

Publication

1. Perales, O., Roman, F. and Arocha, M. ,2005, Uso de Gomas Recicladas para Tratamiento de Efluentes, Interview published in EL NUEVO DIA, one Puerto Rican main newspaper on June 20th, 2005.
2. Perales, O and Roman, F.,2005, Removal of Heavy Metal Ions and Organic Solvents, Invited Lecture at the AIDIS Conference,Isla Verde, Puerto Rico, September 30th, .
3. Perales, O., Roman, F. and Arocha, M., 2006, The use of crumb rubber for the removal of organic solvents from aqueous Solutions, Lecture presented at the University of Texas-El Paso on December 15, 2006.
4. Use of Recycled Crumb Rubber to Remove Organic Solvents from Aqueous Solutions, Poster presentation at the 2nd Senior-ACS Conference, La Parguera, Puerto Rico, November 2005.
5. Crumb Rubber Evaluation as Absorbent for Tetracycline Antibiotic from Aqueous Solutions. Poster presentation at the 26th Puerto Rico Interdisciplinary Scientific Meeting. Cayey, Puerto Rico, March 2006.
6. Use of Recycled Crumb Rubber to Remove Organic Solvents from Aqueous Solutions Poster presentation at the 26th Puerto Rico Interdisciplinary Scientific Meeting. Cayey, March 2006 and at the "12th Drinking Water Seminar", May 22-26, San Juan, Puerto Rico.

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. Waste tires crumb rubber samples were kinfdly provided by REMA Inc, a Puerto Rican recycling company located in Caguas.

The capability of waste tires crumb rubber to remove organic solvents such as xylene, toluene and ethylbencene as well as antimicrobials of the type Tetracycline (TC) from aqueous solutions has been confirmed by batch wise sorption experiments at room temperature. As a complement to these studies, the adsorption of As(III) species was also evaluated. Preliminary studies with 5 ppm As solutions did not provide a clear evidence of adsorption. The As removal from mre dilute concentrations will be evaluated after installing the Atomic Absorption unit to be bought thanks to funds granted to the PIs by the Solid Waste Management Authority. This system is expected to be operational at the end of 2006.

The removal of organic solvents by waste tires crumb rubbers was a highly efficient and fast process. Sorption experiments verified that rubber particles (mesh 14-20 and mesh 30) were capable to remove more than 90% of the organic solvents in the first 30 minutes of contact at room temperature. For similar initial concentrations of the solvents, their removal efficiency and the corresponding rubber up-taking levels were dependent mainly on the solvent structure and the ratio weight crumb rubber/volume of solution. The solution pH did not affect significantly the removal efficiencies. For instance, up to 99, 95 and 77% of xylene, ethylbenzene and toluene respectively, were removed from starting 30 mg/L solutions. The solution pH was 6 and the rubber concentration 10g/L. The corresponding up-take capacities were 55, 48 and 24 mg/g rubber. The sorption capacity of crumb rubber was xylene > ethylbenzene > toluene, whereas higher crumb rubber concentration enhanced the corresponding up-taking levels.

Crumb rubber was also a very promising adsorbent for tetracycline (TC) from aqueous solutions. When 14-20 mesh crumb rubber was contacted with a 9.9 ppm TC solution, the net removal efficiency was 48.7 %. This value considered the observed degradation of the TC as suggested by the control tests. The removal efficiency was increased up to 58% when crumb rubber mesh 30 was used. Evidently, the higher specific surface of the smaller sizes (mesh 30) should have exposed a large concentration of adsorption sites, considered to be the carbon black nanoparticles embedded in the rubber matrix.

2. Statement of the Critical Problem

Protecting water bodies (surface, aquifers and coastal) from contamination is essential for health and safety. 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. Antimicrobials such as Tetracycline (TCs) are of common veterinarian use to prevent epidemics and increase the weight gain in the animals. Very recently, the presence of these antimicrobials in water streams has been verified in Europe and the United States. This type of water pollution has raised environmental concerns based on the fact that up to 90% of the antibiotics fed to animals can be excreted in their active form. Therefore, the use of manure from antibiotic-treated animals as fertilizer and their wash-off by irrigation of rain precipitation should alter the microbial composition and ecology in the receptor soil as well as the quality of receptor water bodies. Diluted concentrations of antimicrobials can also selectively kill susceptible bacteria and favor the growth of resistant microorganisms, which in turn can become a pool of resistant genes. On a local basis, it has been detected that Puerto Rican tissues samples of cattle, calf and swine tissue samples contained excessive levels of agricultural residues. The violations were due to the presence of excessive antimicrobials in the animal tissue.

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.

Accordingly, the search of different alternatives to expand the re-use possibilities for scrap tires sounds justified. The present proposal is focused on the systematic evaluation of crumb rubber as a suitable material to remove inorganic, organic solvents and antimicrobials from aqueous effluents through a low-cost and easy-to-scale technology based on the sorption properties of this waste material. The remediation option addressed by this proposal is based on the presence of carbon black, zinc oxide, and sulfur in crumb rubber, with potential capability to absorb/adsorb and precipitate hazardous species from aqueous solution. This fact has been verified by preliminary results obtained in the first part of our work with Cu(II), Cd(II) and Pb(II) species. The sorbent 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.

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

This research work considered the following main objectives:

i. To optimize the sorption capability of crumb rubber for organic species from aqueous solutions. In order to maximize the up-takes and sorption rates of crumb rubber, alternatives for its activation (chemical) were also evaluated. Then, the sorption capability of granular crumb rubber for xylene, toluene and ethylbenzene was systematically investigated. Preliminary test of As(III) removal was also included.

ii. To asses the sorption capability of crumb rubber for antimicrobials (Tetracycline) from aqueous solutions.
iii. To asses the sorption rates and loading-capacity as a function of crumb rubber particles concentration, particle size and solution pH. It was considered the sorption behavior of the different target species under room temperature conditions in order to use the results in real effluents during the following stages of the research.

Timeline of activities

1) Physical and chemical stability of granular crumb rubber in aqueous media. The results of this part of the study were reported last year.
2) Chemical activation of crumb rubber for the removal of organic solvents.
2) Preliminary work on the adsorption of As(III).
3) Optimization for sorption of organic compounds: xylene, toluene and ethylbenzene.
4) Batch equilibrium and kinetic tests for sorption of tetracycline

4. Methods and Procedures

Granular crumb rubber, screened at different mesh sizes, will be kindly provided by REMA Corp. a tire rubber recycling company located in Caguas, Puerto Rico. It is estimated that a maximum of 4-kilograms of dry crumb rubber will be used for the sorption tests. This crumb rubber will be stored in appropriate containers.

4.1 Experimental Procedures

The basic set-up for the sorption tests includes temperature-controlled water shaker baths, stirrers, pH-meters, filtration and drying units. All quantitative analyses will be carried out in Dr. Felix Roman's laboratory. The term sorption here is used to include both *adsorption*, which refers to the retention of solutes by the surfaces of a solid material, and *absorption* which refers to the retention of the solutes within the polymeric matrix. Sorption processes result from physical, chemical and electrostatic interactions between the solid surfaces and the sorbate.

i. Sorption experiments

The following parameters were evaluated in batch equilibrium sorption experiments: average size of rubber particles, concentration of hazardous species, pH, and crumb rubber/solution w/w ratio. Sorption capability of crumb rubber will be evaluated for room-temperature conditions. To evaluate the role of carbon black on the different compounds sorption, a reference carbon black used by the rubber industry was tested to estimate its sorption capacity for TC. Synthetic solutions bearing the targeted species were prepared in distilled/dionized water. Solution pH was adjusted by suitable amounts of NaOH or HNO_3. Prepared solutions were then contacted with granular crumb rubber in Erlenmeyer flasks (inorganic species) immersed in a temperature-controlled water bath shaker. Samples and blanks were run in duplicate. After determining the pH of the solutions after the contact period, they will be filtered trough membrane filters and submitted for quantitative analyses by atomic absorption and/or ICP-OES techniques. In the sorption kinetic experiments, aliquots will be obtained at different time intervals and submitted for quantitative analyses of the residual species contents right after filtration. During the first step of the experimental work, the sorbent will be contacted with solutions containing single species.

The batch sorption tests for the organic compounds and antimicrobials 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, were kept at approximately 1 ml. In a typical run, 240 ml of 30 ppm of each organic solvent was contacted for 6 hours with crumb rubber 10, 5.0, 1.0, 0.5 y 0.1 g/L. Samples were withdrawn at different contact times using the micro-extraction technique in solid phase. Sorption tests were carried out by triplicate at inicial pH values of 1.5, 6.0 y 9.0.

iii. Activation experiments

Ten grams of crumb rubber were treated with 100 mL of 2.5, 5.0 and 10.0% nitric acid or 2.5% sodium hydroxide solutions for 24 hours. Crumb rubber was also treated under acid (HNO3, 5% v/v) and alkaline conditions (NaOH, 2.5% v/v). Each acid and alkaline treatment was for 24 hours at room temperature. After activation, crumb rubber samples were dried at room temperature conditions for 48 hours. Dried particles were then be contacted with solutions bearing organic contaminants. Thermal activation tests will be carried in the next stage of our project.

4.2 Quantitative analyses

Inductive Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) and Atomic Absorption Spectroscopy (AAS) are widely used in the determination of toxic metals in environmental matrices and will be used in this project for the quantitative evaluation of the sorption and desorption experiments. ICP-OES has multi-elemental capabilities, good sensitivity, high precision, accuracy, wide dynamic range and cost effectiveness. US EPA method 200.7 is based on the ICP-OES technique and used for the determination of heavy metals including As in aqueous solutions. The concentration of the organic compounds in the aqueous, gas and solid phases were determined by solid phase microextraction (SPME) and gas chromatography mass spectrometry. A Finnigan Gas Chromatography-Mass/Spectrometry/Mass Spectrometry system was used for quantitative analyses of organic solvents in aqueous solutions. In turn, EDTA has been used to increase extraction of higher concentrations of TCs in order to improve recovery by chelating metal ions in solution.

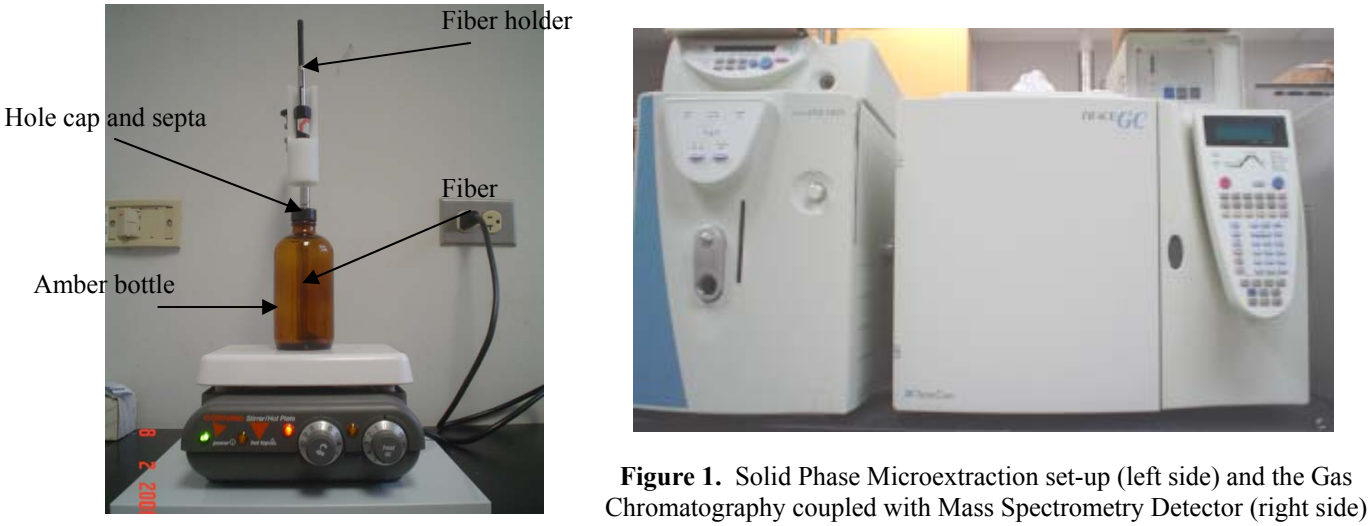


Figure 1. Solid Phase Microextraction set-up (left side) and the Gas Chromatography coupled with Mass Spectrometry Detector (right side)

5. The Sorbent: Waste Tires Crumb Rubber

Crumb rubber was provided by REMA Corporation a tire rubber recycling company located in Caguas, Puerto Rico.

Figure 2 REMA crumb rubber (Mesh 14 – 20). Size of tire rubber particles looks very homogeneous.

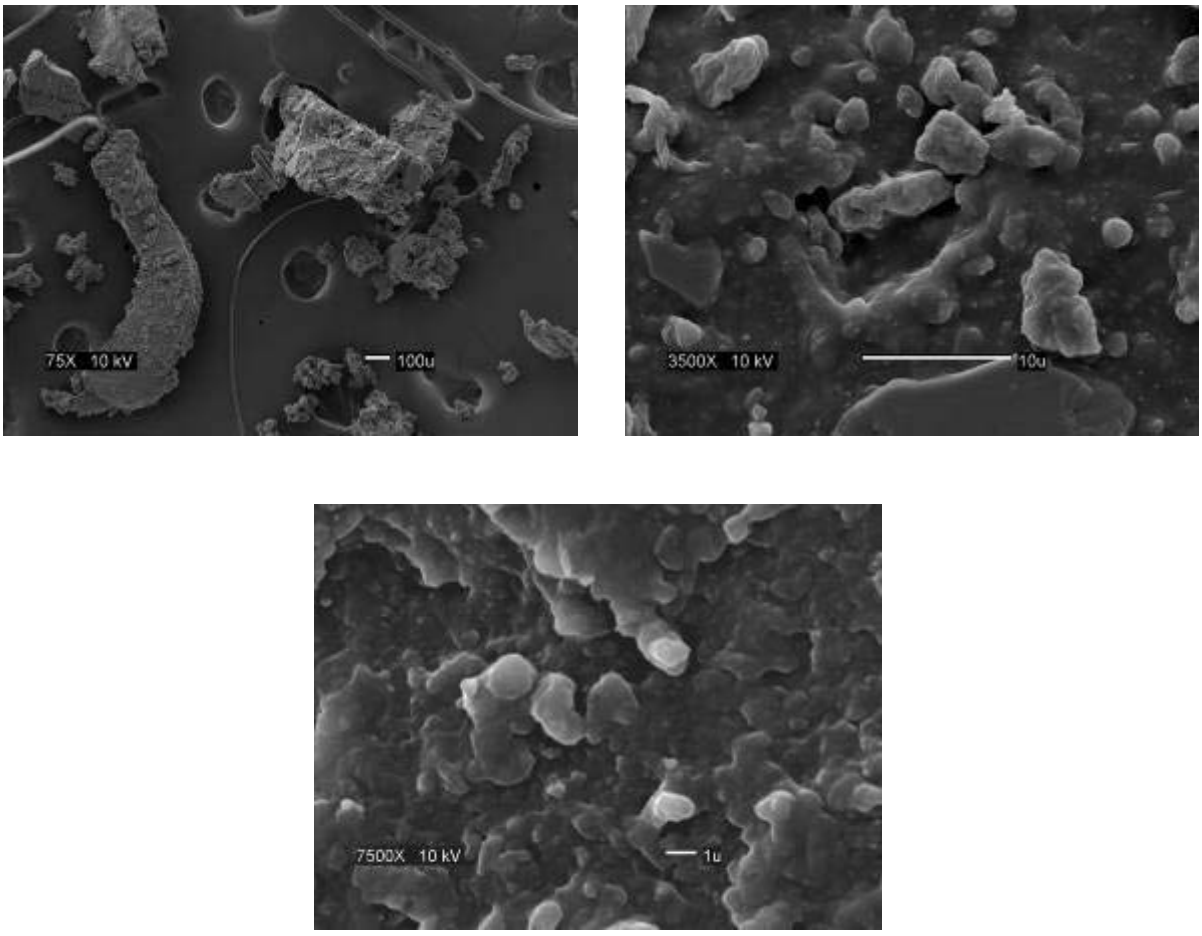


Figure 3 SEM pictures of crumb rubber. SEM analyses a very irregular surface roughness although with non observable porosity.

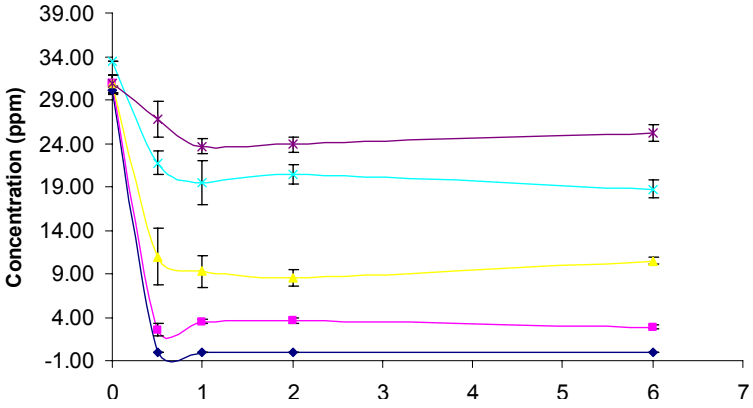
6. Principal findings and significance.

6.1 Sorption of organic solvents

Our recent work verified the very fast sorption of organic species by crumb rubber. Most of the organics were sorbed within the first 30 minutes of contact. Results of the sorption test at different pH values and concentrations of crumb rubber between 0.1 and 10 g/l, are summarized as follows. Quality controls (QC) of 30 ppm for each solvent were run in all experiments. Results were accepted if the error was below 20%. Ethylbenzene, toluene and xylene are non polar compounds which have low solubility in water (see table 1.1), and low concentrations of these compounds assure complete solubility. For that reason, we decided to keep constant the concentrations of analytes (30 ppm) and vary the concentrations of crumb rubber to get desired sorbent/solution ratios.

i. Removal of organic solvents at pH 6.0

a. XYLENE



b. TOLUENE

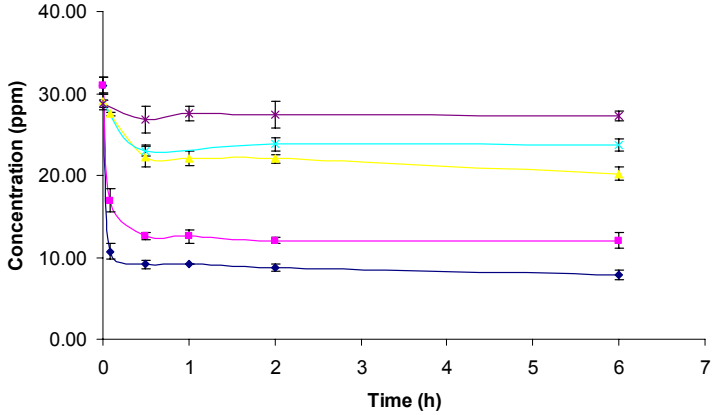
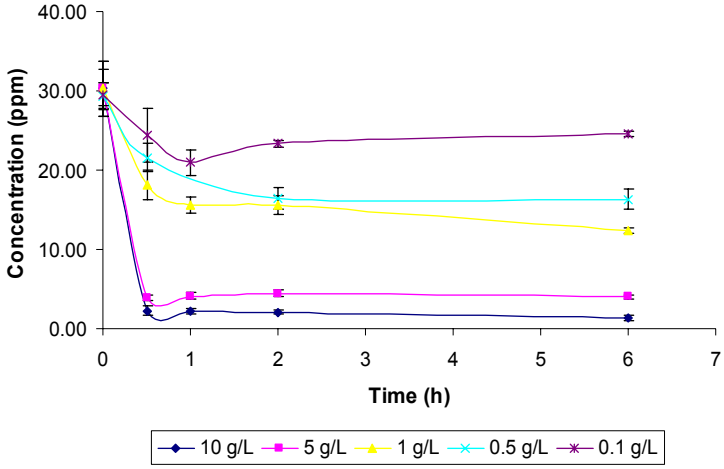


Figure 4. Sorption of ethylbenzene, toluene and xylene by 14-20 mesh crumb rubber. The concentration values in g/l correspond to the ratio weight crumb rubber/volume of solution. The initial concentration of organic solvent was 30 ppm and pH 6.0.

c. ETHYLBENZENE



The capability o clearly demonstrated by attained results. T) was highly efficient and

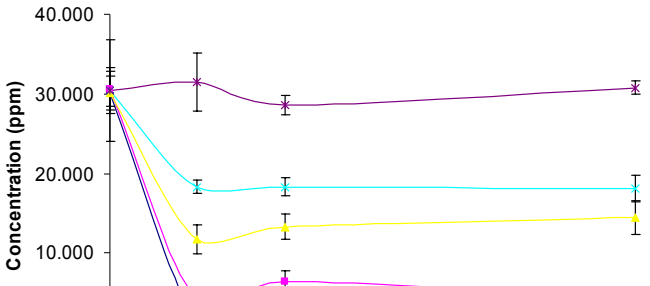
rapid. Most of the pollutants (above 90%) were removed in the first 30 minutes of contact time for suitable concentration of crumb rubber. These results are in good agreement with previous works (Guanasekara, 2000). Xylene was completely removed when 10 g/L of crumb rubber was used (which is the common adsorbent concentration used in the common practice). This high affinity of crumb rubber for xylene was followed by ethylbenzene and, lastly, toluene. Toluene was the highest solubility in water (515 mg/L); then, the partition between the crumb rubber and water is expected to be significantly different from the ones observed for xylene and ethylbenzene having solubilities of 200 mg/L and 152 mg/L, respectively. Xylene and ethylbenzene are more hydrophobic and, as expected, will be absorbed by the crumb rubber matrix more easily and rapid. Terminal concentrations exhibited a rising trend when the concentration of crumb rubber was less than 10 g/l. This behavior was expected because the lesser the amount of adsorbent, the lower the concentration of adsorption sites. At 0.1 g/L of crumb rubber, a minimum amount of pollutant was removed. Observed behavior is characteristic for complex sorbent like crumb rubber where all matrix is the host for active adsorption sites. As also shown in Figure 4, more than 40% of xylene and ethylbenzene were removed for crum rubber concentration as low as 0.5 g/l. The removal efficiency decreased down to 17 and 18% for ethylbenzene and xylene, respectively, when the crumb rubber concentration was 0.1 g/L (that means 100 times less crumb rubber than at 10 g/L).

The chemical composition and structure of crumb rubber is the key to understand its sorbent capability. Isoprene and butadiene are hydrocarbon chains present in crumb rubber that can interact with the alkyl groups of organic solvents. In turn, the presence of methyl groups in adjacent carbons in the structure of o-xylene can be considered as responsible for its adsorption due to a strong chemical affinity with hydrocarbon groups in the rubber matrix. This favorable chemical affinity between the methyl groups and the hydrocarbon ones in rubber can explain the very rapid and efficient removal of xylene by the crumb rubber. The second group in affinity is the ethyl group, which is longer than the methyl one. It could be the reason why ethylbenzene, host of ethyl groups, is removed by crumb rubber. The length of the ethyl group can be related to the comparatively les adsorption of ethylbenzene than toluene. Styrene is also a constituent of tire rubber; its aromatic ring will enable the interaction of styrene with all three organic solvents under study. On the other hand, the participation of carbon black in the sorption process can not be ruled out. Carbon black, 10-50 nm in diameter, exhibits a quite large superficial area and a well known adsorption capability.

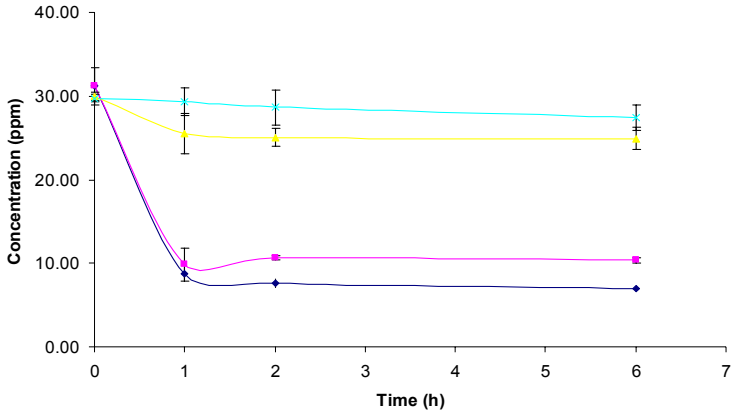
ii. Removal of organic solvents at pH 1.5

The trends in the removal efficiency did not exhibit major changes in comparison with those results at pH 6. In the first 60 minutes the majority of solvent was removed. Samples taken after 30 minutes of contact could not be analyzed because the system was not in equilibrium and the variability was high. It explains why the corresponding error bars for these conditions. A 10 g/L concentration of crumb rubber with an initial concentration of 30 ppm removed 95% of xylene at pH 1.5 which can still be considered excellent removal efficiency. The sorption behavior of toluene and xylene at 0.1 g/L crumb rubber was not considered due to the minimum sorption observed at low concentrations of crumb rubber.

a. XYLENE



b. TOLUENE



c. ETHYLBENZENE

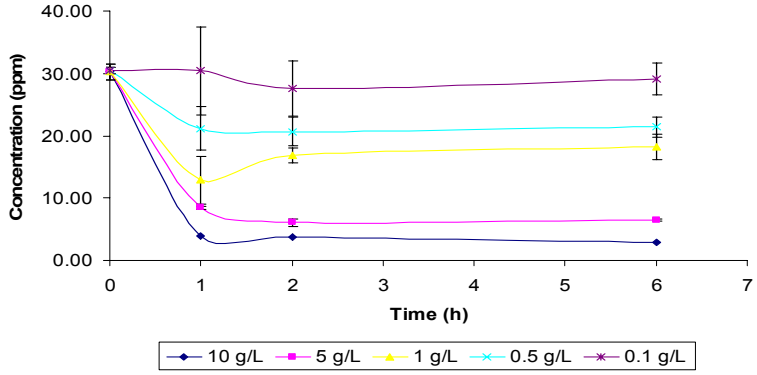


Figure 5. Sorption of ethylbenzene, toluene and xylene by 14-20 mesh crumb rubber. The concentration values in g/l correspond to the ratio weight crumb rubber/volume of solution. The initial concentration of organic solvent was 30 ppm and pH 1.5.

iii. Xylene removal at pH 9.0 and 5 g/L of crumb rubber

As evidenced by the data given in Figure 6, alkaline pHs did not affect the sorption behavior of xylene. As expected, the sorption behavior of organic solvents in presence of crumb rubber is practically a pH-independent process.

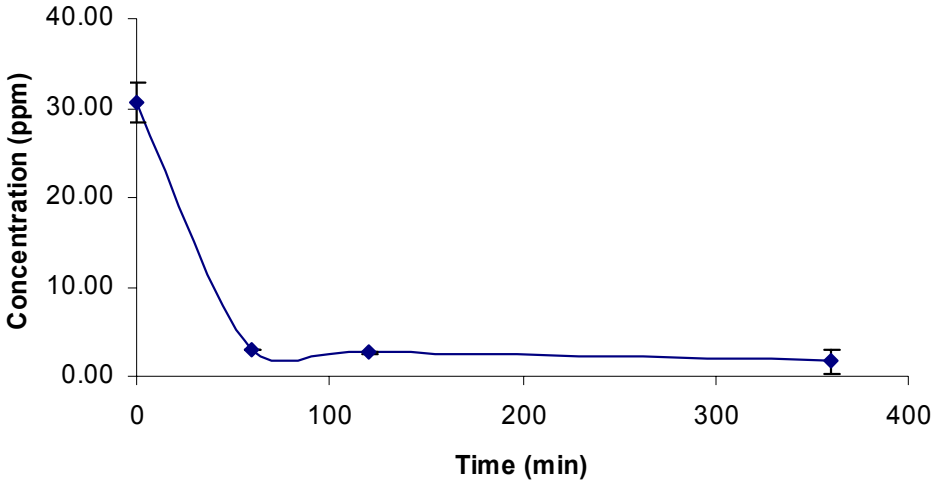


Figure 6. Sorption of xylene by 14-20 mesh crumb rubber (5 g/l). The initial concentration of organic solvent was 30 ppm and pH 9.0.

iv. Adsorption Isotherms

For most organic compounds the parameter 1/n is lest than 1 and values near 1 indicate rapidly removal at high concentration that decrease quickly when the concentration goes down. The other parameter is K_f and this indicates the adsorptive capacity or loading factor of the sorbent and a large value means high removal capacity. As the data in Tables 1 and 2 shows, the Langmuir isotherm better fitted the data for toluene and xylene at pH 6.0; and ethylbenzene and toluene at pH 1.5. In turn, Freundlich isotherms described better ethylbenzene at pH 6.0 and xylene at pH 1.5. Guanasekara et al. (2000) and Kim et al., (1997) worked with toluene and different kinds of rubber as sorbents. Both groups modeled their data using the Freundlich isotherm and found K_f values between 265-297 and 'n' values ranging from 0.993 to 0.991. In our work, we found 166.1 and 767.3 for K_f values; and 1.2683 and 0.6194, for n values, at pH 6.0 and 1.5 respectively. Accordingly, the crumb rubber we have used in the present research exhibited a better sorption capability.

TABLE 1 Parameters of linear, Freundlich and Langmuir isotherms for ethylbenzene, toluene and xylene at pH 6.0.

Compound	ISOTHERM							
	Linear		Freundlich			Langmuir		
	m	r^2	1/n	K_f	r^2	b	Q^o	r^2
Ethylbenzene	1935.8	0.9694	0.9728	1750.9	0.9697	0.04869	44247.8	0.9521
Toluene	581.1	0.9242	1.2683	166.1	0.9916	0.01372	10230.8	0.9987
Xylene	1963.4	0.9430	0.9913	1949.1	0.9779	0.04389	454545.5	0.9973

m : slope
i : intercept
r^2 : R square
n : Freundlich constant

K_f : Freundlich constant
b : Langmuir constant
Q^o : Maximum amount adsorbed

TABLE 2 Parameters of linear, Freundlich and Langmuir isotherms for ethylbenzene, toluene and xylene at pH 1.5.

Compound	ISOTHERM							
	Linear		Freundlich			Langmuir		
	M	r^2	1/n	K_f	r^2	b	Q^o	r^2
Ethylbenzene	767.4	0.9546	0.9155	946.6	0.9789	0.02327	41322.3	0.9833
Toluene	149.2	0.7976	0.6194	767.3	0.8975	0.05008	10101.0	0.9648
Xylene	1278.4	0.9577	0.874	1703.1	0.9746	0.05876	32051.3	0.9689

m : slope
i : intercept
r^2 : R square
n : Freundlich constant

K_f : Freundlich constant
b : Langmuir constant
Q^o : Maximum amount adsorbed

6.2 Chemical activation of crumb rubber

Our results suggested that the chemical activation of crumb rubber under acid, alkaline or acidic/alkaline conditions did not represent any improvement on the sorption capability of the crumb rubber in comparison with the non-activated one. Therefore, it seems advisable to consider the use of crumb rubber with no need for any acid/alkaline pre-treatment.

6.3 Sorption of tetracycline (TC). LC-MS/MS Chromatography Results

We used the selected reaction monitoring mode (SRM) and the internal standard method for the quantification of the concentration of TC in aqueous solutions. Crumb rubber and carbon black were used as sorbents. Prior to LC/MS quantitative analyzes, it was necessary the optimization of the measurement conditions. It included: chromatography separation, retention time, the ionization and detection mode of the ions, LOD, LOQ and Ion Trap Parameters. We took the MS and MS/MS spectrum of tetracycline (TC) and an internal standard (demeclocycline, DMC). TC showed the (M+H) ion in 445.10 m/z with product ions located at 427.10 and 410.20 m/z. The optimized chromatography conditions were: Mobile phase acetonitrile 40% deionized water, 1 % formic acid, pH 2.43; 0.40 mL/min

The LOD and LOQ of TC were estimated at 0.03 ppm and 0.10 ppm, respectively. Those values were 0.005 ppm and 0.05 ppm for DMC. MS spectra of DMC internal standard (IS) presented a (M+H) ion in 465.10 m/z and product ions in 448.08 and 430.00 m/z, due to fragmentation from parent ion (465.10 m/z). For MS quantification, the product ions in 410.20 and 427.17 m/z were monitoring to obtain the extract ion chromatogram (EIC) for TC. The corresponding calibration curve was adjusted to a quadratic polynomial. Presented results were obtained for 168 hours of contact time, pH 3.80 and initial TC concentration of 10.00 ppm. 14-20 mesh crumb rubber (CR), with and without acid washing (in HNO_3 2.5 %), and non-washed 30 mesh crumb rubber (CR) were used in the sorption experiments. For purposes of comparison, the sorption of TC in presence of carbon black was also carried out.

i. TC removal by crumb rubber mesh 14-20

Crumb rubber was capable to remove TC from aqueous solutions. Results are summarized in Figure 7. As seen, a drop in TC concentration from 9.85 down to 4.13 ppm when 14-20 mesh crumb rubber was used. After subtracting the degradation of TC, evidenced by the control samples, the net removal efficiency was 48.7%. In those tests with non-washed crumb rubber, the presence of Zn species (from ZnO in crumb rubber) should have competed with the crumb rubber polymeric material and/or carbon black as active adsorption sites for TC. Accordingly, TC molecules should have formed some complex with Zn sites in the crumb rubber at the earlier sorption stages. This mechanism could explain the larger removal efficiencies observed in the non-washed crumb rubber particles. This interpretation could also explain the abrupt drop in TC concentration at the beginning of the sorption process followed by an increase in its concentration, probably due to the release of the Zn-TC complex into the bulk solution. The stability of metal-TC complex is well documented in the scientific literature. Also, our ICP measurements have verified the continuous release of Zn ions in the course of the contact period. It also explains the rise in pH that would arise from the leaching of ZnO in the rubber. Further drop in TC concentration could be attributed to the Zn-TC complex adsorption by carbon black nanoparticles embedded in the rubber particles. It must be remarked that the solutions' pH at the end of the contact period differed from the initial value (3.80). For instance the final pH for the sorption test using mesh 14-20 crumb rubber without acidic treatment was 5.71. Evidently, this change in pH during contact period must have affected the removal capability of the

crumb rubber. Future tests will be carried out under constant pH conditions to evaluate the real effect of this parameter on the sorption capability of crumb rubber.

When the sorption test was performed using acid washed mesh 14-20 crumb rubber, the terminal concentration was 6.02 ppm, which suggested a different absorption mechanism. In the acid washed crumb rubber, most of the Zn sites should have removed by the acid solution, limiting the sorption capability. It will also decrease the concentration of probable Zn-TC complexes in solution, which could have affected negatively the removal efficiency. Additional work must be carried out to clarify these probably mechanisms.

ii. TC removal by carbon black

The removal of TC by carbon black (N-330) was a highly efficient process. The concentration of carbon black in solution was equivalent to its concentration in the rubber particles (around 22% in weight). Therefore, 2.2 g/l of carbon black was considered equivalent to 10 g/l of crumb rubber. In these tests no change in the solution pHs during the contact period were noticeable. The TC removal varied between 97.80 and 100.00 %. Evidently, there is a great affinity between TC molecule and carbon black. On this basis, a major exposure of the carbon black nanoparticles to the TC solution should improve the removal efficiencies. It was attempted by using a crumb rubber mesh 30, which exhibit a particle size smaller than for mesh 14-20.

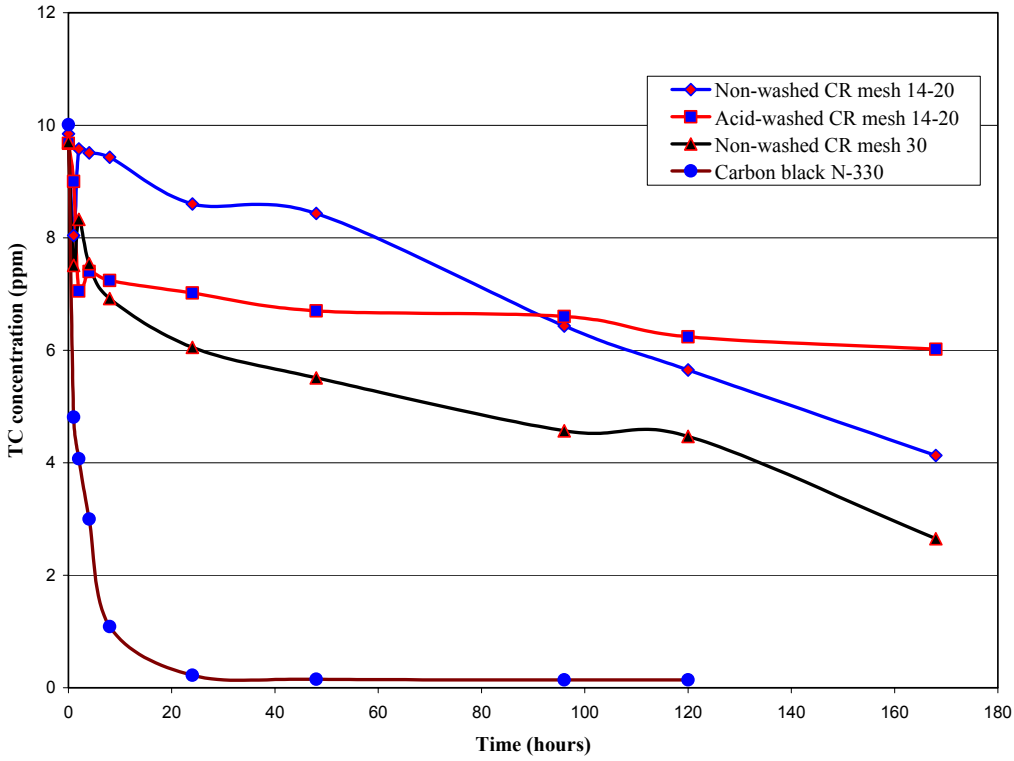


Figure 7. Variation in TC concentration with time for crumb rubber mesh 14-20, with and without acid washing, crumb rubber mesh 30 and carbon black (2.2 g/l). The concentration of crumb rubber was 10 g/l and the starting TC concentration 30ppm. Initial pH 3.8.

iii. TC removal by crumb rubber mesh 30

Almost 60% of the TC was removed by using crumb rubber mesh 30 (after subtracting the degradation of TC indicated by control samples). This result confirmed our previous hypothesis, i.e. the removal capability of crumb rubber will be improved by increasing the exposure of carbon black nanoparticles. Despite this favorable effect of rubber particle size on the sorption efficiency of TC, and from an industrial application viewpoint, the handling of small particles of crumb rubber (mesh 30, for instance) is not an easy task. To address this issue, future experimental work includes column tests to evaluate the capability of crumb rubber in a single and serial sorption stage(s).

6.4 Sorption of As(III)

The purpose of these 'screening-test' was to determine the sorption capability of crumb rubber in presence of As(III) ions species in aqueous phase. Preliminary tests with 5ppm of As did not show any clear evidence of actual adsorption of As by crumb rubber. A more detailed investigation will be undertaken using the AA unit to be purchased thanks to ADS funds granted to the PIs. The corresponding results will be discussed in the progressive reports to be presented in the next phase of our research.

7. Student Support

Section 104 Awards

Students	Base Grants
Undergraduate	1
Masters	3
Ph.D.	0

8. Achievements and Awards

- **Toyota Foundation** awarded to the research group the amount of $16,000 (01 year). The money is being used to cover stipends of graduate students participating in the project.
- **The Inter American Society of Sanitary Engineering and Environmental Sciences (AIDIS)** awarded the First Prize on Research to the work: ***"Remoción de BTEX por Partículas de Goma Recicladas en Soluciones Acuosas"***, presented by UPRM-PRWRERI last September 2005.
- Recently, the **Waste Management Authority (ADS) awarded $140,000** for the acquisition of major instrumental equipment. The grant is for instrumentation only. The instrumentation to be purchased will allow us to analyze concentration at the parts per billion (ppb) levels, as required for studies on mercury and arsenic (these two species are addressed in the present proposal as a complement to our studies on heavy metals). Legal considerations to be included in the contract have been completed. The final contract is expected to be signed by June 2006. Included equipment will be purchased and installed at UPRM before December 2006.
- Based on promising preliminary results, the research goals have been expanded to the evaluation of crumb rubber as potential sorbent for polyaromatic hydrocarbons (PAHs) in aqueous solutions (Phase-III of the present Project).

- The present research group involves: three faculties (02 from Materials Science and 01 from Environmental Chemistry) and three 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.

Others:

- Although the HPLC/GC-MS methods for tetracycline were standardized, it works only for highly concentrated solutions (above 50ppm).
- In order to evaluate the sorption behavior at more dilute TC concentrations (<5ppm) a direct measurement by GC-MS must be considered.
- The atomic absorption unit to be purchased by ADS funding will allow us to analyze more dilute concentrations of As and Hg.

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

FIELD METHODS IN HYDROLOGY AND HYDRAULIC

Synopsis

Problem and Research Objectives:

The Department of Civil Engineering and Surveying at the University of Puerto Rico, Mayagüez began 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 and engineers in these vital areas. There is also a need to provide 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 programs 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 development was in charge of four specialists in the areas of surface water, groundwater hydrology and hydraulics; they were: Dr. Ingrid Padilla, Dr. Raúl Zapata, Dr. Jorge Rivera-Santos and Dr. Walter F. Silva.

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 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, data acquisition and procedures for the analyses. The analyses include, but are not limited to, statistical analyses, completeness and consistency tests, and frequency.
2	Evaporation and Evapotranspiration	Students maintain and take daily measurements from a Class A Evaporation Pan during the entire semester. The data collected is used to calibrate various evaporation models. The students model the evaporation process at different sites and assess the results. The models take into account energy balance, aerodynamics, and 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. Parameters estimation of commonly used models was 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 take stage and stream discharge measurements using stage markers, topographic surveys, and flow velocity propellers. 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. A calibration session for flow measurement devices was also given.
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 transport 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.

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

6	Groundwater measurements and hydraulic measurements. Pumping and Specific Capacity Test	The objective of this activity is to introduce the students to: (1) groundwater measurements and instrumentation; (2) determination of groundwater natural and forced gradients; (3) single point, field data evaluation; (4) analysis of temporal field data uncertainty; (5) analysis of single- well response to groundwater extraction; and (6) evaluation of well production (yield capacity) and efficiency. Groundwater levels are measured in the 2 wells installed for this project and 5 observation wells in a nearby site. All well locations and elevations are tied to UTM and Lambert Coordinates and Mean Sea level elevations. Groundwater gradients are estimated using the water level elevations. 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
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.

The field/experimental activities required the acquisition and installation of hydrologic/hydraulic instrumentation and the development of experimental sites. Mayor instrumentation acquired and installed, related site development, and the educational activities for which the instruments are used are included in Table 2. The related site development refers to the site where the instruments have been installed or where they are used.

Principal Findings and Significance:

The course was created as a Civil Engineering course (INCI 6116) and offered during the fall semesters of the 2003-2004 and 2005-2006 academic years. 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. Eight (8) graduate civil engineering students have taken and approved the course: 4 were at the M.S. level and 4 were at the Ph.D. level.

The course scheduled followed the attached *Course Syllabus* (Appendix 1). All field activities were conducted successfully as planned and described in Table 1.

Table 2. Instrumentation and Site Development

Instrumentation	Related Site Development	Educational Activity Relation[1]
Weather Station (Davis Vantage Pro™): Includes raingage, anenometer, UV solar radiation, temperature, relative and humidity sensors, and a cabled data acquisition and storage console.	Placed on the roof of the Civil Engineering Building at The University of Puerto Rico , Mayaguez (Figure 1)	Climatic Variable Analysis, Evaporation, and Evapotranspiration
Class A Evaporation Pan	Placed on the roof of the Civil Engineering Building at The University of Puerto Rico , Mayaguez (Figure 1).	Climatic Variable Analysis, Evaporation and Evapotranspiration
Soil Lysimeter. Includes soil tank and field tensiometers (SoilMoisture Equipment Corp.)	Located in the Civil Engineering Field Site (Figure 1).	Evaporation and Evapotranspiration
Double Ring Infiltrometer (SoilMoisture Equipment Corp), Tension Disk Infiltrometer (SoilMoisture Equipment Corp.)	Variable field sites within the Yaguez Watershed.	Infiltration
Digital Flow Meter (Global Waters)	Variable field sites within the Yaguez and Añasco Watershed.	Surface Water Hydraulic Measurement, Sediment Transport
Depth sounder (Hondex) , Range finder (Bushnell), and Inclinometer (Suunto), sediment samplers	Variable field sites within the Yaguez and Añasco Watershed.	Surface Water Hydraulic Measurement, Sediment Transport
Wells (2), well pump (75 gpm, 5HP, 230V)	Located in the Civil Engineering Field Site (Figure 1)	Pumping and Specific Capacity Test, Aquifer Test and Groundwater Sampling
LeverLoggerTM (Solinst™), model 3001, 30M pressure transducer and data logger	Located in the Environmental and Water Resources Engineering Laboratory	Pumping and Specific Capacity Test, Aquifer Test, Surface Water Hydraulic
Water Level Logger (Global Waters)	Located in the Environmental and Water Resources Engineering Laboratory	Pumping and Specific Capacity Test, Aquifer Test, Surface Water Hydraulic
Water Level Meter (Powers)		Pumping and Specific Capacity Test, Aquifer Test
GPS (Garmin)		Surface Water Hydraulic Measurement, Sediment Transport , Pumping and Specific Capacity Test, Aquifer Test

Most of the field activities were successfully implemented and carried out. Students learned about the instrumentation and methods of hydrologic and hydraulic field activities and applied theoretical concepts on the analysis of the measured parameters. Reports are written by students for all activities. Presentations on the integrated hydrologic-hydraulic processes were offered by the students.

Two ground water wells were drilled: a pumping well and an observation well near the Civil Engineering building at the UPRM campus. The approximate location of the wells is shown in Figure 1. The wells are about 300 ft from each other. The construction parameters of the wells

are summarized in Table 3. 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. These wells will be used in future ***Field Methods in Hydrology and Hydraulic Measurements*** and Groundwater Hydrology Courses.

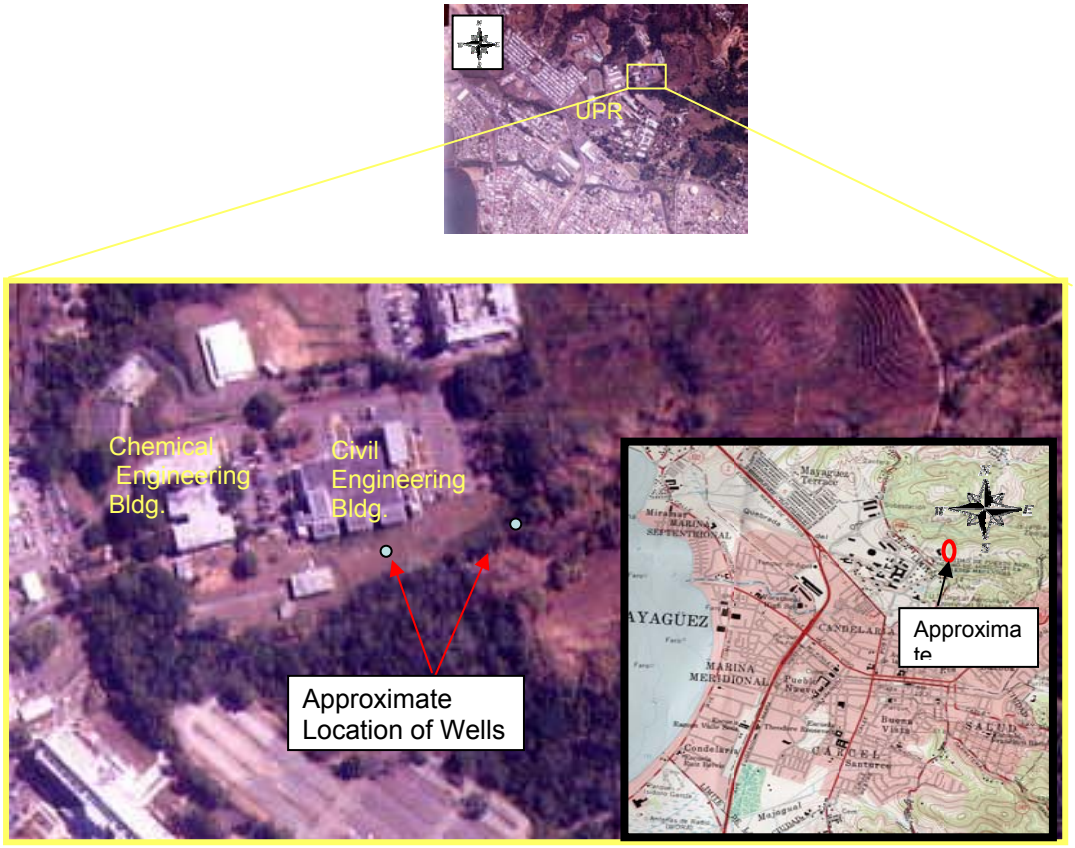


Figure 1. Civil Engineering Wells Field

Table 3. 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 six (6) individual written report grades. Students were not evaluated in the oral presentation, but 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 ACCOMPLISHMENTS

Eight students enrolled officially in the created course in ***Field Methods in Hydrology and Hydraulic Measurements*** over two academic semesters as summarized in Table 4. Other students, however, have been indirectly trained from this project, including students from other courses and students working in the Environmental and Water Resources Engineering Laboratory. Eleven other students registered in *Groundwater Hydrology* during the 2nd academic semester of 2004-2005 and 2005-2006 were trained in basic groundwater measurements (water levels). Other faculty members from the Geology and Civil Engineering departments 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.

Table 4. Students registered in the course.

Field of study	Academic Level				Total
	Undergraduate	MS	Ph.D.	Post Ph.D.	
Chemistry					
Engineering:					
Agricultural					
Civil		4	4		8
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		4	4		8

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 To[p]ics:

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 (9/3 0)	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
E-mail: wsilva@uprm.edu
Office Hours: MWF 10:30-1 2:30
(Other hours by Appointment)
Co-Instructors: Dr. Jorge Rivera-Santos, Raul Zapata, Dr. Ingrid Padilla e-mail: riveraj@uprm.edu, Zapata@ce.uprm.edu, Ingrid@ce.uprm.edu

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 a (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. Plagiarism: the penalty for academic dishonesty is failure on the piece of work.
    - **Use of beepers and cellular phones is prohibited during class hours**

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.

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Information Transfer Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	4	0	0	0	4
Masters	9	0	0	0	9
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	14	0	0	0	14

Notable Awards and Achievements

The Inter American Society of Sanitary Engineering and Environmental Sciences (AIDIS) awarded the First Prize on Research to the work: Remoción de BTEX por Partículas de Goma Recicladas en Soluciones Acuosas (Removal of Inorganic, Organic and Antimicrobials Contaminants from Aqueous Solutions by Waste Tire Crumb Rubber), presented by UPRM-PRWRERI last September 2005.

Publications from Prior Projects

None