Puerto Rico Water Resources & Environmetal Research Institute Annual Technical Report FY 2017

Introduction

The Puerto Rico Water Resources and Environmental Research Institute (PRWRERI) is located at the Mayagüez Campus of the University of Puerto Rico (UPRM). The Institute is one of 54 water research centers established throughout the United States and its territories by Act of Congress in 1964 (P.L. 88-379) and presently operating under Section 104 of the Water Research and Development Act of 1984 (P.L. 98-42), as amended. The Puerto Rico Water Resources Research Institute was established in April 22, 1965, as an integral division of the School of Engineering at the College of Agricultural and Mechanic Arts, the official name of UPRM at that time. An agreement between the Director of the Office of the Water Resources Research Institute of the Department of the Interior and the University of Puerto Rico at Mayagüez was signed in May 25, 1965. This agreement allowed the Institute to receive funds as part of the Water Resources Act of 1964. In June 1, 1965, the Chancellor of UPRM appointed Dr. Antonio Santiago-Vázquez as the first director of the Puerto Rico Institute of Water Resources Research. The first annual allotment of funds for fiscal year 1965 was $52,297.29.

Since its inception 53 years ago, the Institute has had eight directors in nine appointment periods as shown in the table below.

No.	Name	Period of Appointment	Years in Appointment
1	Dr. Antonio Santiago-Vázquez	1965 – 1968	3
2	Eng. Ernesto F. Colón-Cordero	1968 – 1972	4
3	Eng. Felix H. Prieto-Hernández	1972 – 1974	2
4	Dr. Roberto Vázquez (acting director)	1974 – 1975	1
5	Dr. Rafael Ríos-Dávila	1975 – 1980	5
6	Dr. Rafael Muñoz-Candelario	1980 – 1986	6
7	Eng. Luis A. Del Valle	1986 – 1989	3
8	Dr. Rafael Muñoz-Candelario	1989 – 1994	5
9	Dr. Jorge Rivera-Santos	1995 – Present	23

The official name of the Institute was changed in 2005 to Puerto Rico Water Resources and Environmental Research Institute to emphasize and give the right place to environmental sciences research.

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 and environmental 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 and the U.S. To accomplish these objectives, the Institute identifies Puerto Rico's most important water resources research needs, funds the most relevant and meritorious research projects proposed by faculty from island's high level education institutions, encourages and supports the participation of students in funded projects, and disseminates research results to scientists, engineers, and the public.

Since its creation, the Institute has sponsored a substantial number of research projects, supported jointly by federal, state, municipal, private, and University of Puerto Rico's funds. Through its website, the Institute's work is more widely known to the Puerto Rican and world communities and, at the same time, provides means of information transfer with regard to the reports produced through the institute's research activities.

The Institute is advised by an External Advisory Committee (EAC) composed of members from water resources and environmental related government agencies, both federal and state levels. This committee virtually convenes annually to established research priorities and to evaluate and recommend proposal for funding under the 104-B program. The EAC has representation from the private sector as well. During EAC meetings, members are supported by the Institute’s Director and Associate Director. Due to recent retirement of some of the members and continues changes in government directorate officials, the Institute’s Director is engaged in recruiting new members for next fiscal year. New agency representatives that may participate in the EAC include the PR Department of Natural and Environmental Resources (PRDNER), Federal Emergency Management Agency (FEMA), US Fish and Wildlife Service (FWS), and US Army Corps of Engineers (CoE).

Research Program Introduction

The Institute functions as a highly recognized advisor to the industry and government sectors on water resources and environmental 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.

FY-2017 104-B base grant supported two new projects. The project titled “Willingness to pay for water scarcity eradication and water service attributes in Puerto Rico: Results from contingent valuation and choice experiments methods” (Project No. 2017PR176B) has as objectives to: (1) use a contingent valuation method to estimate residents’ willingness to pay for water scarcity eradication in Puerto Rico, (2) use a choice experiments method to estimate residents’ willingness to pay for water service attributes in Puerto Rico, and (3) use a variety of strategies to disseminate research results to stakeholders at multiple levels. Results from this study can be used to create efficient policy designs and raise awareness regarding water scarcity-related phenomena in Puerto Rico.

This project is under a no-cost extension, so, it is still in progress. In September 2017 Puerto Rico was affected by hurricane Irma and two weeks later devastated by Hurricane María. Thus, survey distribution was not possible. Surveys were rescheduled to be distributed from March to May 2018.

The second project is titled “Atrazine degradation with visible-light photocatalysis using iron-grafted TiO2 nanoparticles: Evaluation and applications for water treatment,” which focused on assessing the viability of Fe(III)TiO2 nanoparticles to effectively photodegrade Atrazine (ATZ) in water solutions under the influence of visible light. The goal is to develop and implement a water treatment process consisting of gravity-influenced inclined plane impregnated with iron-grafted TiO2 nanoparticles for the degradation of pesticide-related contaminants under the influence of sun light via photodegradation. To accomplish and complete this endeavor, it was proposed a two-year project encompassing four main phases: 1) chemical modification of the TiO2 surface; 2) viability of Fe(III)-TiO2 for photodegradation of ATZ; 3) immobilization of Fe(III)-TiO2 nanoparticles in the PVC matrix; and 4) design, construction and evaluation of a lab-scale inclined plane for effective photodegradation of ATZ under the influence of visible light. The accomplishment of this project will provide essential data to set the foundations for the development and establishment of an easy-to-use, energy-efficient water treatment process for the removal/destruction of pesticides-related contaminants in water.

This project is under a no-cost time extension (NCTE) due to the aftermath of Hurricanes Irma and Maria in Puerto Rico. The project and few critical tasks were affected and delayed. For this reason, the project was granted a NCTE until February 28, 2019.

FY2017 characterized for various influential events. The first was a student strike in March 2017 that closed the University of Puerto Rico for almost two months delaying the starting of the projects. Then in September, Puerto Rico was hit by two mayor Hurricanes in less than two weeks. The category 5 hurricane Maria devasted the island resulting in a total power blackout that lasted for over a month at UPRM. To this day, there are several sectors in the rural area of P.R. that are still with no electrical power. Other mayor event has to do with the economic crisis the government of Puerto Rico is going through. As part of the harsh economic measures the Commonwealth of PR is forcing, the budget of the University of Puerto Rico was cut 50%, which means the financial support the Institute was receiving was eliminated.

The economic crisis the Island is thriving with has not allow the government to establish normal operations one year after taken office. This translate to a high turnover of high governmental officials. Although new appointments have been continuously proposed, this turnover does not allow the director to establish sound relationships with this agencies. Nevertheless, the relationship that was initiated during few years ago with the PR Planning Board (PRPB) is still active during this time. This government agency, among other responsibilities, is in charge of receiving, analyzing and resubmitting all hydrologic-hydraulic studies for flood plain delineations and modifications according to FEMA's regulations. In June 2016, PRPB approved by resolution and adopted the new "Guidelines to Prepare Hydrologic and Hydraulic Studies in Puerto Rico," guidelines prepared by PRWRERI. Now, the PRWRERI has been invited to submit a proposal to develop a new set of rules and guidelines to design stormwater sewer systems incorporating the latest technology in Low Impact Development techniques.

Continuing collaboration with the Puerto Rico Department of Natural and Environmental Resources (PRDNER) has resulted in various externally funded projects. PRDNER has adopted the "Guidelines to Prepare Riverbed Material Extraction and Sediment Transport Studies in Rivers of Puerto Rico" prepared by the Instutute. This project consisted in the evaluation of current engineering practices for conducting riverbed material mining and transport studies in the Island. The new guidelines included two reports, namely, "Guidelines to Prepare Riverbed Material Extraction and Sediment Transport Studies in Rivers of Puerto Rico: Technical Manual" and "Guidelines to Prepare Riverbed Material Extraction and Sediment Transport Studies in Rivers of Puerto Rico: Practice Handbook." These products will influence the DNER's decision-making process related to the approval of new sand and gravel extraction permits from rivers and other type of projects that affect natural water bodies.

The Institute continued seeking research funds through the submission of research proposals to federal agencies. During FY2017, the Institute submitted two proposals to NRCS and PR Planning Board. The proposal submitted to NRCS was approved and the one submitted to PRPB is pending on the issuance of a contract.

Willingness to pay for water scarcity eradication and water service attributes in Puerto Rico: Results from contingent valuation and choice experiments methods

Basic Information

Title:	Willingness to pay for water scarcity eradication and water service attributes in Puerto Rico: Results from contingent valuation and choice experiments methods
Project Number:	2017PR176B
Start Date:	3/1/2017
End Date:	2/28/2019
Funding Source:	104B
Congressional District:	PR-098
Research Category:	Social Sciences
Focus Categories:	Economics, Drought, Water Supply
Descriptors:	None
Principal Investigators:	Hector Simon Tavarez, Carmen I Alamo, Mildred Cortés

Publications

There are no publications.

Progress Report

PI: Héctor Tavárez

Project Number: 2017PR176B

Title: Willingness to pay for water scarcity eradication and water service attributes in Puerto Rico: Results from contingent valuation and choice experiments methods

Submission Date: May 2018

Work Performed

A. Introduction

This semi-annual report presents the problem under evaluation, overall objective of the project and the specific research objective for this year. I describe the selected methods to fulfill the objectives. Preliminary research results are presented followed by some of the limitations for this period. This report covers all processes, responsibilities and achievements from March to August 31st, 2017. However, it should be noted that funds were not available until June 2017.

B. Problem and Research Objectives

The vast majority of residents in Puerto Rico receive water from the Puerto Rico Aqueduct and Sewage Authority (PRASA) government agency. In recent years, residents in Puerto Rico have suffered from water scarcity due to reductions in water supply. As a result, residents have experienced changes in water services, including weekly water service interruptions and restrictions. For instance, the government has imposed a ban to various outdoor activities, such as carwash and water irrigation for home gardens. These changes in water services affect residents' livelihood in diverse ways, which may result in social conflicts and health and sanitation concerns in the country. Residents in Puerto Rico may experience water scarcity again in the future due changes in climatological characteristics and increases in broken pipelines. In this study, we will estimate residents' willingness to pay (WTP) for water scarcity eradication and for water service attributes. Respondents' WTP is used in economics as a proxy of the value of the good under consideration. Our results can be used by the PRASA and the Department of Environmental and Natural Resources of Puerto Rico to evaluate the viability of projects aimed at eradicating water scarcity or improving water service attributes.

The overall objective of this study is to contribute to the understanding of the impacts of water scarcity on residents' livelihood. The specific objective for this year is to use a contingent valuation method to estimate residents' WTP for water scarcity eradication in Puerto Rico.

C. Methodology

We conducted a literature review about residents' preferences and WTP for overall water service improvements. Several factors were identified that may affect residents that are suffering from water scarcity. This information was used to develop a draft of the survey instrument needed to fulfill the research objective. The draft of the survey instrument was subsequently distributed in focus group sessions.

We conducted two focus group sessions at the Agricultural Experiment Station in San Juan, which is part of the University of Puerto Rico. We invited participants from different age groups, gender and education level to the meetings. This allowed us to better understand participants' preferences for water service improvements. Additionally, we conducted two meetings at the Puerto Rico Aqueduct and Sewage Authority (PRASA) to gather insights about potential collaboration with the agency and information that can help with the overall study design. Information obtained from these meetings were subsequently used to improve the design of the survey instrument, including the contingent valuations. Information obtained from focus groups was also useful to improve the design of the choice experiments method need to fulfill objective 2, which will be completed during the second year of this project. We will use Sawtooth Software for the distribution of surveys via internet.

D. Principal Findings

Improving the valuation exercise

Respondents provided useful information with regard to the contingent valuation and choice experiment methods that allowed us to make changes to the valuation exercise. A total of twelve participants completed the draft of the survey instrument. Activities were organized for a larger number of participants, but some participants could not attend to the focus group sessions, even though they confirmed attendance. However, focus groups for choice experiments typically do not involve a high number of participants. All respondents understood the contingent valuation question. However, half of participants stated that the information provided before the choice experiments method is not sufficient to understand the valuation exercise. Additionally, two participants reported that one of the attributes presented in the choice experiment needs to be better explained. The rest of respondents understood the choice experiments methods and found the valuation exercise to be either easy or very easy to understand. Participants also provided useful information that allowed us to make changes to both the cost attribute and payment vehicle. The questionnaire was later modified using information from focus groups.

Socio-demographic information of participants

Table 1 reports descriptive statistics of socio-demographic characteristics of individuals. Respondents age varied from 27 to 58 years old and all respondents had either a bachelor degree or higher education. Although we tried to have a more heterogeneous group in terms of education level across participants, all participants had a high level of education. Forty-one percent of respondents were male and household income varied from $3,000 to $7,000. This may be problematic because this group of respondents may have more access to available resources (e.g., economic, social and technological resources, infrastructure) and experience different necessities than residents with lower education and household income. Therefore, we discussed information provided in focus groups with personnel of PRASA to account for preference heterogeneity across water recipients. We were informed that overall concerns obtained from focus groups reflect the overall concerns received in the agency by PRASA water recipients.

Table 1: Socio-economic and demographic characteristics of individuals across groups

Variable	Definition	Mean (SD)*
Age	Respondent age	40.25 (12.23)
Education	Education of respondent (1=None, …, 5=Graduate school)	4.5 (0.52)
Gender	Gender of respondent (1= Male, 0=Female)	0.41 (0.51)
Income	Total household income per month (1= less than or equal to $500, 7= more than $7,000)	3.83 (0.72)
Garden	Respondents with a home garden (1=Yes, 0=No)	0.42 (0.51)
Scarcity	Respondents that experienced water scarcity (1=Yes, 0=No)	0.67 (0.49)
Size	Number of people in household	2.67 (0.78)
Dependents	Number of household dependents	1.42 (0.90)

* SD = Standard Deviation

Perception about water uses and household practices

We asked respondents using Likert-scale type questions (1=very important, 5=Not important) to rank the importance of different water uses for household consumption. The most important uses are water for drinking and for home gardening. The least important uses are water for cleaning vehicles and for cleaning surrounding areas. All participants agreed that water for drinking is very important for households. Ninety-one percent of respondents believed that water for home gardening is either important or very important. Ninety-two percent of respondents believed that water for cooking is either important or very important. Ninety-one percent of respondents believed that water for sanitation is either important or very important. Forty-two percent of respondents have gardens in their home.

E. Significance of the Project

Understanding residents' preferences and WTP (i.e., the value of) for water scarcity eradication is important for the design of future policies. If these values are not considered, policy designs could be inefficient in allocating limited resources in terms of failing to achieve social welfare maximization. Some of the causes limiting the use of value estimates in policy design are lack of scientific research. To our knowledge, there are no studies in Puerto Rico about residents' WTP for water scarcity mitigation projects. Thus, more research is needed to provide useful information to decision makers. Estimates of the value residents assign to eradicating water scarcity are critical for evaluating the economic viability of projects aimed at improving water supply. Results from focus group sessions and meetings with PRASA personnel was used to improve the survey instrument needed to estimate residents' WTP for water scarcity eradication and for water service improvements.

F. Limitations

The distribution of the survey instrument was scheduled to begin in September 2017. However, in September 5th 2017 Puerto Rico was affected by Hurricane Irma and two weeks later devastated by Hurricane María. Survey distribution was therefore not possible. Distributing survey instruments after a shock that may impact overall preferences and WTP for the good under consideration can potentially affect research results due to biased estimates. Given the limited access to electricity and internet services that many Puerto Ricans have been experiencing during the last months, survey distribution will start in February 2018. Less than fifty percent of residents in Puerto Rico had access to electricity in November 2017 due to the hurricanes. Access to internet is even more limited.

Student training and support

1. Student 1, MS student from Agricultural Economics and Rural Sociology

Student 1 is one of the lead student for this endeavor and one of the graduate student sponsored by the project. He was in charge of conducting literature review, organizing focus group meetings and analyze data from focus groups. Student 1 is getting trained in the use of Stata and analysis of data. He will continue working in the second phase of this project.

2. Student 2, MS student from Agricultural Economics and Rural Sociology

Student 2 is the other lead student for this endeavor that is sponsored by the project. She was in charge of conducting literature review, organizing focus groups and analyzing data from focus groups. Student 2 is getting trained in the use of Stata and analysis of data. This student will continue working in phase II of the project.

3. Student 3, MS student from Agricultural Economics and Rural Sociology

Student 3 is a graduate student that works with the PI's research group. He was sponsored by other project and was giving support to this project. Also, he is receiving training in data analysis and economic valuation methods. He will continue working in phase II of the project.

4. Student 4, MS student from Agricultural Economics and Rural Sociology

Student 4 is a graduate student that works with the PI's research group. She was sponsored by other project and was giving support to this project. She is receiving training in data analysis and economic valuation methods. She will continue working in the second phase of this project. Both, students 3 and 4 are addressing water-related topics in their master research.

	Base grants	Matching funds*	Total
Undergrad.		2	2
Masters	2	2	4
PhD			
Post-Doc.			
Total	2	4	6

* This column provides information about students who collaborated and received benefits from this project but were not sponsored by the project.

Notable Awards and Achievements.

The principal achievement of this project was to successfully meet with stakeholders and government officials to initiate and maintain a collaborative process. Collaborating with stakeholders and government officials is critical for transdisciplinary studies and addressing concerns that are of interest to all groups.

PUBLICATION CITATION FORMAT:

Articles in Refereed Scientific Journals

Tavárez, Héctor S., Mildred Cortés, Carmen Alamo, *in preparation*, Residents' willingness to pay for water scarcity eradication in Puerto Rico: Results from contingent valuation method

* The other publications and poster presentations related to this project will be developed during the second year.

Atrazine degradation with visible-light photocatalysis using iron-grafted TiO2 nanoparticles: Evaluation and applications for water treatment

Basic Information

Title:	Atrazine degradation with visible-light photocatalysis using iron-grafted TiO2 nanoparticles: Evaluation and applications for water treatment
Project Number:	2017PR177B
Start Date:	3/1/2017
End Date:	2/28/2019
Funding Source:	104B
Congressional District:	PR-098
Research Category:	Water Quality
Focus Categories:	Treatment, Toxic Substances, Water Quality
Descriptors:	None
Principal Investigators:	Pedro Javier Tarafa, OMarcelo Suarez, Sylvia RodriguezAbudo

Publications

1. Huang C, Lacen A, Tarafa P. Fe(III)-Doped TiO2 Nanoparticles Photoactivated Under Visible Light. Poster presented at the Research Experience for Undergraduates in Reconfigurable & Multifunctional Soft Materials Poster Session. Museo de Arte y Senado Académico (MuSA), UPR-Mayagüez. August 2, 2017.
2. Dosh A, Lacen A, Tarafa P. A Study of Various TiO2 Doping Methods with Fe (III) for Use in the Photocatalytic Degradation of Atrazine. Poster presented at the Research Experience for Undergraduates in Reconfigurable & Multifunctional Soft Materials Poster Session. Museo de Arte y Senado Académico (MuSA), UPR-Mayagüez. August 2, 2017.

Progress Report

PI:	Pedro J. Tarafa, PhD
Project Number:	2017PR177B
Title:	Atrazine degradation with visible-light photocatalysis using iron-grafted TiO_2 nanoparticles: Evaluation and applications for water treatment.
Submission Date:	December 1, 2017

Brief Introduction

This report is intended to provide an update to include preliminary results and accomplishments for the aforementioned research project within the first 7 months of funding (March – September 2017). Due to the direct landfall of Hurricane Maria over Puerto Rico, the submission was delayed.

The overall goal of the research is to develop, test and implement an economical, feasible, and sustainable system to treat pesticide-polluted waters through an inclined, gravity-influenced plane system embedded with surface-modified TiO_2 nanoparticles able to photo-activate in the visible light spectrum (i.e. >400 nm). The current stage of the research comprises the: (1) establishment of a protocol for doping Fe(III) ions on TiO_2 for an effective visible-light photoactivation; and (2) evaluation of the iron-grafted TiO_2 nanoparticles photodegradation potential against atrazine under visible light.

Student Training for the Related Period

Below there is a list of all students (graduate and undergraduate) that have been involved in the project, either funded or non-funded.

1. Alba Lacen, MS student from Civil Engineering
   Alba is the main graduate student sponsored by the project. She is in charge of studying and developing the iron doping protocol for the TiO_2 nanoparticles. Also, she has been conducting the characterization of the Fe(III)TiO_2 nanoparticles and designing the treatability studies for atrazine degradation under visible light. She mentored two undergraduate students during the past summer for the Research Experience for Undergraduates (REU) program and still mentors one undergraduate student during the current semester. Alba has been trained with different doping techniques, involving both physical and chemical treatments. In addition, she has been trained with the use of High Pressure Liquid Chromatography (HPLC) and Total Organic Carbon (TOC) vial analysis for the quantification of atrazine, and UV/vis spectrophotometer and X-ray diffraction (XRD) for the characterization of the iron-grafted TiO_2 nanoparticles composite.

2. Carlos Huang, Undergraduate student from Chemical Engineering
   Carlos is an undergraduate student from UPRM in his junior year. He joined this project in Summer 2017 through an REU program sponsored by NSF to develop an undergraduate research under the tutelage of Dr. Tarafa and Alba Lacen. He provided help and support for the execution of the selected protocols for the doping of iron particles on the TiO_2 nanoparticles. Also, helped in conducting literature reviews. He was

trained in basic laboratory skills and with the use of UV/vis spectrophotometer. Carlos still works in Dr. Tarafa's research group.

3. Austin Dosh, Undergraduate student from Chemical Engineering
   Austin is an undergraduate student from Western Michigan University who also joined Dr. Tarafa's research group during Summer 2017 to conduct undergraduate research through the REU program. Austin provided help and support for the execution of the selected protocols for the doping of iron particles on the TiO_2 nanoparticles. Also, helped in conducting literature reviews. He was trained in basic laboratory skills and with the use of UV/vis spectrophotometer.

Results Dissemination

1. Huang C, Lacen A, Tarafa P. **Fe(III)-Doped TiO_2 Nanoparticles Photoactivated Under Visible Light**. Poster presented at the Research Experience for Undergraduates in Reconfigurable & Multifunctional Soft Materials Poster Session. Museo de Arte y Senado Académico (MuSA), UPR-Mayagüez. August 2, 2017.

2. Dosh A, Lacen A, Tarafa P. **A Study of Various TiO_2 Doping Methods with Fe (III) for Use in the Photocatalytic Degradation of Atrazine.** Poster presented at the Research Experience for Undergraduates in Reconfigurable & Multifunctional Soft Materials Poster Session. Museo de Arte y Senado Académico (MuSA), UPR-Mayagüez. August 2, 2017.

Work Performed

1. Chemical modification of the TiO_2 surface

   In general, four protocols were selected and evaluated for the incorporation of the iron ions onto the TiO_2 (i.e. iron doping). Due to the nature involved in those protocols, they were classified/divided as: (1) physical treatment (PT); and (2) chemical reaction (CR).

   1.1 Iron doping through physical treatment: The PT protocols consisted in the addition of iron in the form of $FeCl_3$ to commercial TiO_2 nanoparticles using ethanol and deionized (DI) water as the solvents. The incorporation of the iron ions onto the TiO_2 surface is accomplished by heat treatment varying temperature, time and the mass of iron. The masses of iron ranged between 1 to 3% molar (Fe/Ti) while the temperature and time evaluated ranged between 850 – 1,050 C and 2 – 6 h, respectively. The final iron-doped TiO_2 nanocomposite is depicted as $Fe_xTi_{1-x}O_2$ and for purposes of this report, it will be referred as PTA (physical treatment- A). Details of the procedure are described elsewhere (Liu et al., 2013).

   A second iron-doped TiO_2 nanocomposite was developed employing this same procedure, but adding additional iron to the PTA in a hydrochloric acid (HCl) solution. This last step did not involve heat treatment. The final iron-doped TiO_2 nanocomposite is depicted as Fe(III)-$Fe_xTi_{1-x}O_2$ and for purposes of this report, it will be referred as PTB (physical treatment- B).

1.2 Iron doping through chemical reaction: This protocol consisted in the synthesis of TiO_2 through a chemical reaction using a titanium dioxide precursor. The iron ions are then added and incorporated onto the TiO_2 by heat treatment. Three different iron-doped TiO_2 nanocomposites were developed and evaluated employing this approach, named CR1, CR2 and CR3 where CR stands for Chemical Reaction.

1.2.1 CR1: The procedure for the synthesis of this nanocomposite is adapted from Zaifeng et al. (2011). The TiO_2 precursor was tetra-isopropyl-orthotitanate (TTIP). The method required the use of ethanol as the solvent and nitric acid to adjust pH. The source of iron was $Fe(NO_3)_3$. Three different molar masses of iron were employed ranging from 2, 4 and 6%. Afterwards, heat treatment is applied for temperatures and times ranging from 450 – 750 C and 2 – 6 h, respectively.

1.2.2. CR2: The iron-doped TiO_2 nanocomposite obtained by this approach was quite similar to the CR1. However, the amount of chemicals, solvents and pH changed. The method did not require heat treatment. This protocol is adapted from Choi et al. (1994).

1.2.3 CR3: This approach involved the same steps and chemicals as in the CR2, but heat treatment is provided at the end for the nanocomposite. The methodology details are described by Hung et al. (2008).

2. Characterization and evaluation of photocatalytic properties for the Iron-doped TiO_2

Four different doping protocols were used, which were modified to achieve better optical properties maximizing the absorbance in the range of visible light. These protocols were:

a. Iron doping using pure, commercial TiO_2 as the starting material, named PTA and/or PTB.
b. Iron doping using a TiO_2 precursor, named CR1
c. Iron doping using a TiO_2 precursor, named CR2
d. Iron doping using a TiO_2 precursor, named CR3

The iron-doped TiO_2 composites were then analyzed using a spectrophotometer. Photo-spectroscopy gave an idea of what wavelengths of light the substance was absorbing. If it is absorbing a certain wavelength, then it is being energized by that wavelength; hence, by observing the absorbance in the visible light spectrum, predictions can be made about the doping and its effect on the photocatalytic activity of the TiO_2 composite. An XRD analysis was also performed to determine the crystalline polymorph structure (i.e. anatase or rutile) of the iron-doped TiO_2 nanoparticles and to confirm whether or not the iron doping was achieved.

2.1 PTA and PTB:

Since three parameters (temp, time and mass) for three different values on each parameter were considered on the doping protocol, a total of 27 combinations, and hence 27 samples, were obtained for each PTA and PTB. Figure 1 shows the general behavior of the iron-doped TiO_2 particles absorbance with heat treatment temperature. It can be seen that for a temperature of 850 C a well-defined absorbance peak is seen in the visible light range at 462 nm. However, a defined peak is not observed on the spectrographs for 1050 C and 950 C under the visible light spectrum. Hence, it can be concluded that there is an absorbance in the visible light spectrum for the nanocomposite thermally treated at 850 C.

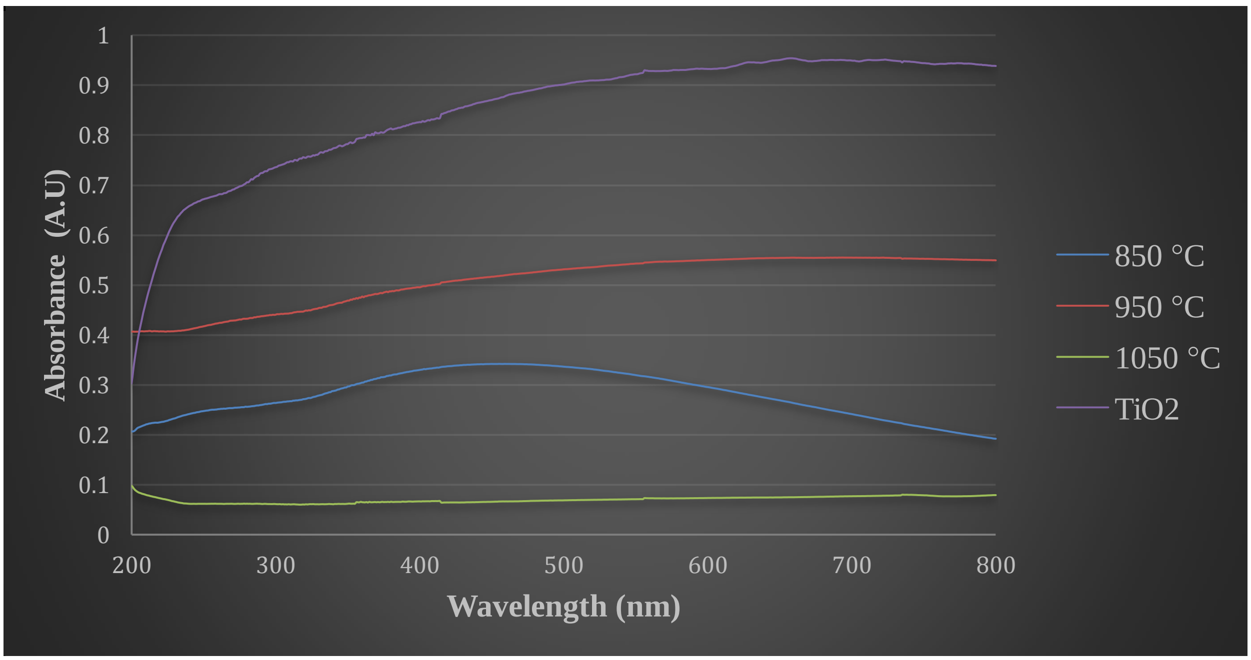

Figure 1. Spectrographs on the light absorbance of the iron-doped TiO_2 nanocomposite for three different heat treated temperatures

An XRD analysis was then conducted to evaluate the integrity of the TiO_2 polymorph phase. Figure 2 shows the diffractograms for two iron-doped TiO_2 samples thermally treated at 850 C having two different iron masses, and a third diffractogram consisting of a pure, non-doped TiO_2 sample.

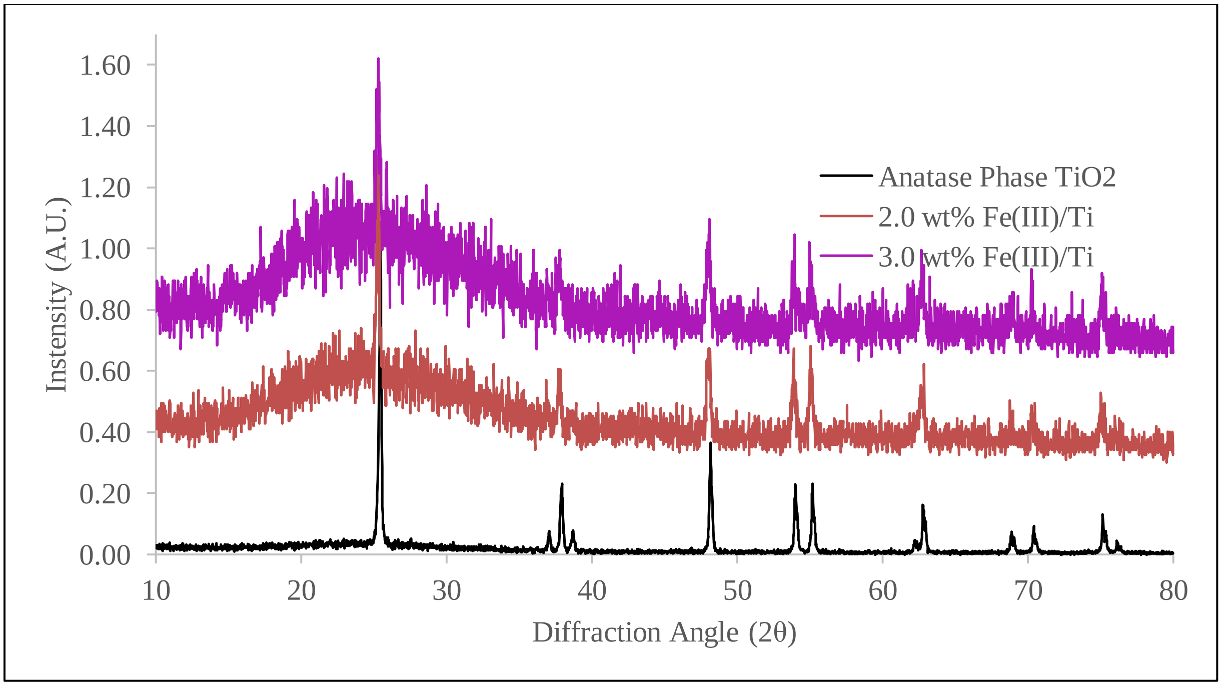

Figure 2. Diffractograms of PTB samples thermally treated at 850 C and 2 h

From Figure 2 it can been seen that the TiO_2 anatase crystalline structure was not compromised in the iron-doped TiO_2 nanocomposites when compare with the pure TiO_2 sample. No unusual peaks are observed in the iron-doped TiO_2 diffractograms that could indicate the appearance of a second phase or some secondary compounds in the TiO_2. Table 1 summarizes the detected wavelengths for the absorbance obtained for each iron-doped mass and heat treatment time at 850 C on both PTA and PTB.

Table 1. Detected absorbance wavelength for PTA and PTB for different iron masses and thermally treated times at 850 C

Dopant concentration (% M)	Heated time (h)	Absorbance wavelength for PTA (nm)	Absorbance wavelength for PTB (nm)
1	2	516	470
1	4	516	471
1	6	496	502
2	2	453	496
2	4	473	471
2	6	459	481
3	2	464	**594**
3	4	492	507
3	6	489	469

From the data shown in Table 2 it is concluded that the combination yielding the highest absorbance in the visible light spectrum (594 nm) was PTB with an iron doping of 3% M and a thermal treatment temperature of 850 C and 2 h.

2.2 CR1

This iron-doping procedure (as in CR2 and CR3) entails a chemical reduction using a TiO_2 precursor, TTIP. A total of 27 samples were obtained for a combination of dopant concentration, heat treatment temperature and time. The absorbance wavelengths for all 27 samples are shown in Table 2.

Table 2. Absorbance wavelength for CR1 composite for different dopant concentrations and thermally treated temperatures and times

	Absorbance wavelength for 2% M Fe/Ti			Absorbance wavelength for 4% M Fe/Ti			Absorbance wavelength for 6% M Fe/Ti		
Temperature (C)	2 h	4 h	6 h	2 h	4 h	6 h	2 h	4 h	6 h
450	382	409	200	200	200	**416**	287	265	256
600	270	349	269	366	378	354	200	200	347
750	200	324	307	324	319	**562**	310	316	299

From data presented in Table 2, the combinations that yielded the highest absorbance peaks (416 and 562 nm) consisted in 4% doped-iron thermally heated for 6 h at either 450 or 750 C. The rest of the combinations exhibited wavelength absorbance in the ultraviolet (UV) light spectrum. An XRD analysis was performed (Figure 3) to evaluate the polymorph structure. From Figure 3 it is observed a phase change in the crystalline structure for the nanocomposite thermally treated at 750 C, changing from anatase to rutile phase.

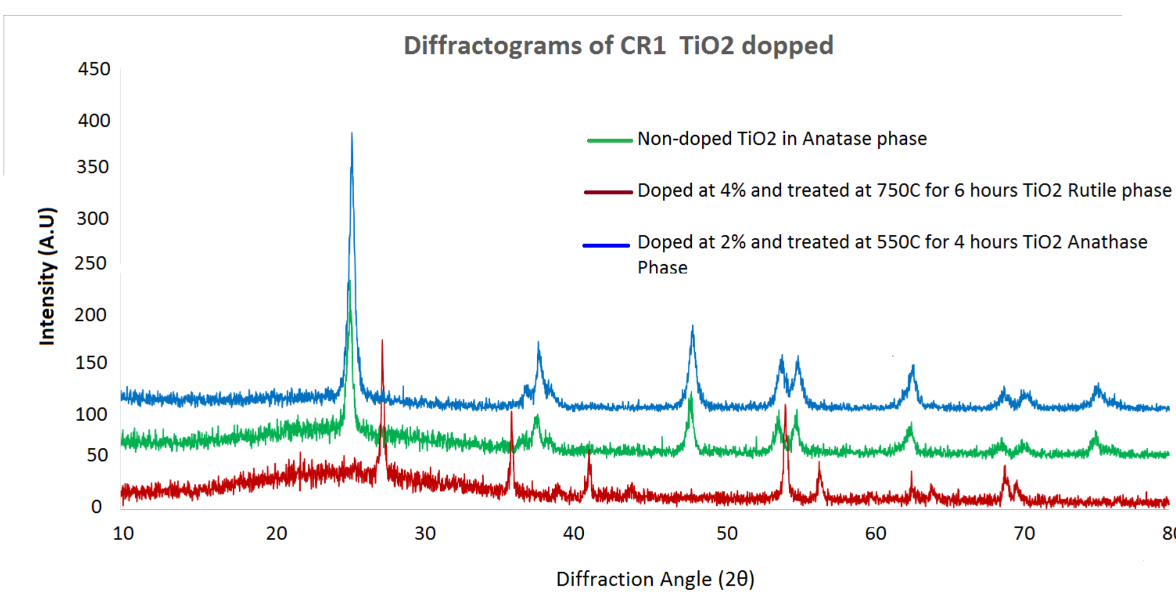

Figure 3. Diffractograms for CR1 nanocomposites

2.3 CR2

The TiO_2 nanocomposite obtained under this protocol was evaluated with both XRD and UV/vis spectrophotometer. A crystalline structure of TiO_2 was not observed and, moreover, the absorbance range decreased compared to a pure, non-doped TiO_2 (refer to Figure 4). Since this composite did not absorb light under the visible spectrum, it will not be easily photoactivated under visible light. Hence, the procedure was not considered for further degradation studies and was discarded.

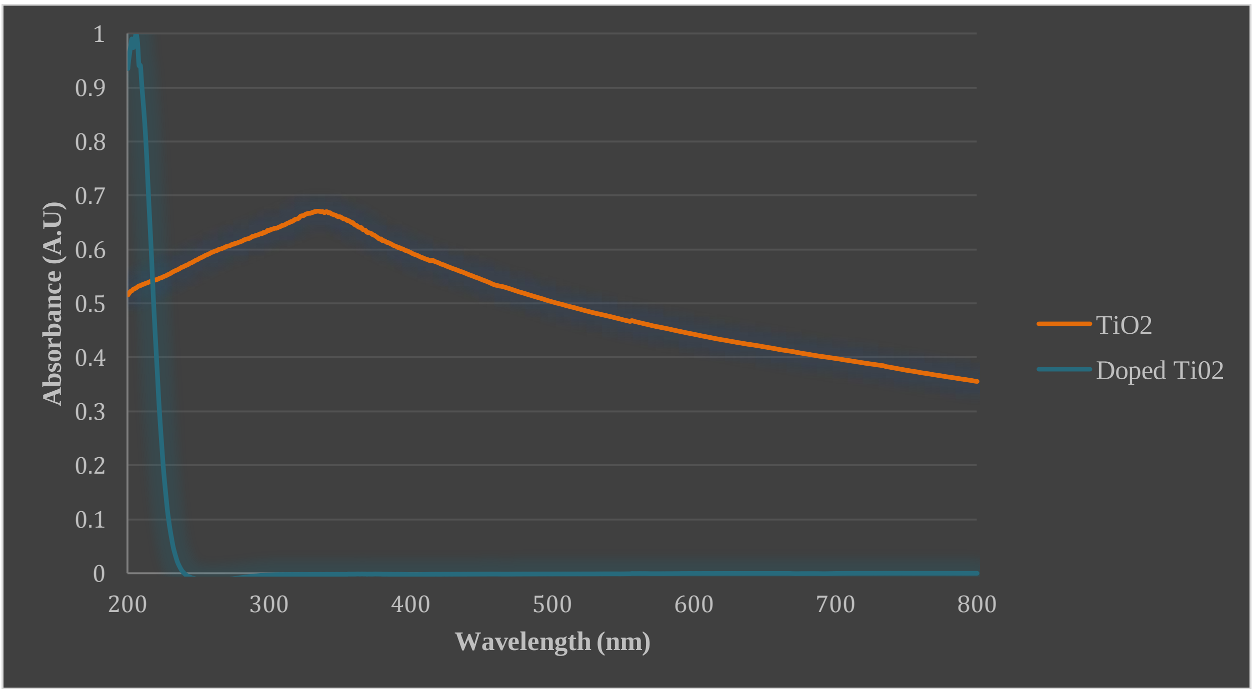

Figure 4. Spectrographs on the light absorbance of the iron-doped TiO_2 nanocomposite for the CR1 protocol

2.4 CR3

This protocol follows the same parameters combinations (dopant concentration, temperature and time) as in CR1, but with different reactants and chemicals quantities. A total of 27 samples (nanocomposites) were obtained. After performing a spectrometer analysis, it was observed that none of the 27 samples were able to absorb light in the visible spectrum. All samples had their absorbance peaks at a wavelength of 200 nm, which falls in the UV light spectrum. Hence, the procedure was discarded.

3. <u>Photocatalytic treatment for the degradation of atrazine</u>

This work is in progress and few preliminary photodegradation tests have been conducted with PTA and CR1. So far, no atrazine degradation has been observed using PTA under visible light. After conducting some literature review, the reason for no photodegradation may be attributed to the nanoparticles size (it may be too large). Currently, we are seeking help to address this. For CR1, little atrazine degradation was detected in the presence of visible light.

Conclusions

From the four protocols evaluated to effectively dope iron ions on the TiO_2 nanoparticles, two of them showed absorbance in the visible light spectrum (> 400 nm). These protocols were PTA/PTB and CR1. The third protocol (CR2) was discarded since the crystal structure of the TiO_2 was not formed and the absorbance range was decreasing. The fourth procedure, CR3, was discarded because despite the combination of parameters, no absorbance results were obtained within the range of visible light. For CR1 procedure, despite having favorable results, only two combinations out of 27 presented visible light absorbance. However, for PTA/PTB all combinations at 850 C showed visible light absorbance.

References

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Information Transfer Program Introduction

Meetings, seminars, technical reports, and a web site are used by the Institute to keep the water resources community and general public informed about advances in research. Approximately once every three or four years, the Institute organizes a major conference on water-related research in Puerto Rico and the Caribbean Islands, in collaboration with US Virgin Islands Water Resources Research Institute, Caribbean office of the USGS, and professional organizations in the region. All these activities facilitate the translation of research sponsored by the Institute into practical applications of direct benefit to industry, government, and the public. The Puerto Rico Water Resources and Environmental Research Institute joined the Hawaii Water Resources Research Center, the Virgin Islands Water Resources Research Center, and the Environmental Research Institute of the Western Pacific in Guam to organize the conference titled "2nd Water Resource Sustainability Issues on Tropical Islands." Next conference is being coordinate with the Islands Institutes for April 2019. This information transfer project is partially funded from 104B program.

Third Conference on Water Resource Sustainability Issues on Tropical Islands

Basic Information

Title:	Third Conference on Water Resource Sustainability Issues on Tropical Islands
Project Number:	2017PR178B
Start Date:	3/1/2017
End Date:	2/28/2019
Funding Source:	104B
Congressional District:	PR-098
Research Category:	Not Applicable
Focus Categories:	Water Supply, Management and Planning, Climatological Processes
Descriptors:	None
Principal Investigators:	Jorge Rivera-Santos, Walter F Silva

Publications

There are no publications.

Progress Report

(As of February 2018)

PI:	Jorge Rivera Santos
Project Number:	2017PR178B
Title:	Third Conference on Water Resource Sustainability Issues on Tropical Islands
Submission Date:	May 2018

The conference was schedule for April 2018 to be held in St. Thomas, VI. Due to the after match of Hurricanes Irma and Maria, the conference has been postponed to a new date to be determined. Several meetings of the host Institutes have been conducted by the directors by phone and person to person during the Annual Director Meeting in DC on February 2018.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	4	0	0	0	4
Masters	5	0	0	0	5
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	11	0	0	0	11

Notable Awards and Achievements

None.