UNIVERSIDAD METROPOLITANA
GRADUATE SCHOOL OF ENVIRONMENTAL AFFAIRS
SAN JUAN, PUERTO RICO

SEDIMENT TOXICOLOGY AND THE HEAVY METAL PHYTOREMEDIATION POTENTIAL OF THREE MANGROVE SPECIES IN PENINSULA LA ESPERANZA, LAS CUCHARILLAS MARSH NATURAL RESERVE, CATAÑO, PUERTO RICO

In partial fulfillment of the requirements for the degree of
Masters in Science in Environmental Management
In Conservation and Management of Natural Resources

By
Marixa Maldonado Román

May 19th, 2014

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IN
CONSERVATION AND MANAGEMENT OF NATURAL RESOURCES

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DEDICATION

To my dad who was the person that inspired me
to become a better professional and to be passionate for what you do;
the first person who found out about the school.
And to the best grandma in the world,
who is with the angels since fall of 2009- she gave the extra strength to
begin the journey of graduate studies that same year.

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Even though the experience in the School was very tough and a little longer than I expected it to be, I am very grateful for the great opportunities I have had since 2009-2014. I started in the clinical / medical road of science at the beginning of my undergraduate studies and have been shifting over these last years to the environmental, becoming a strong defendant of the natural resources of Puerto Rico and worldwide, and passionate about the beautiful forests of Latin America and the Caribbean, including mangrove forests. I have to say that I am a very different human being from the person once entered this School. I know all these experiences will help me become a better professional and person. No matter where I am in the future I will always remember where I started and where I come from.

I am very pleased with the work that was completed with this project and hope it can somehow serve for other students that have a passion for coastal ecosystems. Someone once told me everything was already done with the mangrove ecosystems on the island. For that I will respond that it is a very wrong statement; Puerto Rico, the Caribbean and the tropical regions of Latin America have the talent and the expertise to produce great projects about coastal ecosystems, there is still much to do and know about. Science is not static; it constantly changes over time. There is more to find and more to know about in search for better answers of current challenges like climate change, sea level rise and global warming. Understanding of mangroves could be a great opportunity to comprehend and foresee the new changes that climate change is causing in the coastal ecosystems.

Thank you to all of you for making this great achievement possible!

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LIST OF ABBREVIATIONS

AG OR AVICENNIA GERMINANS- commonly known as black mangrove

AS- Arsenic

BASELINE- is a series of data that was collected using a broad number of samples under strict quality control methods that can give specific ranges of concentrations of an element in an area. These ranges of elements can be used as a reference when collecting new data.

BFC'S-Bioconcentration Factors. Using a previously defined formula, this value is the product of a division of the heavy metal concentration found in the leave and the heavy metal concentration found in sediment.

CD-Cadmium

CR- Chromium

CU-Copper

DNER-Department Of Natural And Environmental Resources Of Puerto Rico

GREEN LEAVES- Leaves from the trees that are new and still attached to the branches

HG-Mercury

HYDROPHYTIC- Is a type of vegetation that grows in water environments.

HM-Heavy metals, define as elements in the periodic table that have a density bigger than the density of water but also used to refer to elements that could be toxic to organisms.

IONS-The simplest chemical form the heavy metals are available in the soils or water

LR OR LAGUNCULARIA RACEMOSA- Commonly known as white mangrove

PB- Lead

PHYTOSTABILIZATION- A way plants can maintain nutrients or heavy metals inside a specific area or inside the body of the plant

PHYTOREMEDIATION- Is a process by which plants can absorb nutrients from surrounding soils, uptaking them from roots and transporting them to other parts of the plant.

PPM- Concentration unit used for heavy metals (unit for mass, for volume is the same as μg/mL)

RM OR RHYZHOPHORA MANGLE- Commonly known as red mangrove

RT-Retranslocation values, this value is a percent obtained by a formula that applies the measure of the heavy metal concentrations in both green and senescent leaves. This value can give an idea of how much the plant is reusing before exporting in the leaves that are about to fall.

SE-Selenium

SEDIMENTS- Upper or top part of the soils usually known as sediments are from soils that are in contact with water.

SENESCENT LEAVES- Leaves that is about to fall from the plant or are already in the soil. These leaves exhibit either a yellowish or brownish color and can be already in a beginning to disintegrate.

SJBE- San Juan Bay Estuary

ZN- Zinc

RESUMEN

Los metals pesados se encuentran en el ambiente de manera natural, pero son los factores antropogénicos los que mayor efecto tienen causando aumentos en los niveles naturales de estos metales. Nuestra área de estudio se conoce como Península La Esperanza, la cual es parte de la cuenca hidrográfica del Estuario de la Bahía de San Juan; una reserva natural y de vida silvestre desde el año 2008. Un método a tomar en consideración para el manejo de los metales en sedimentos se conoce como fitorremediación. Los manglares son el tipo de vegetación predominante dentro de esta área; estos han desarrollado mecanismos internos y externos que les permiten tolerar y estabilizar los metales pesados en los sedimentos circundantes. Este estudio se enfocó en tres especies de manglar de las 4 especies que se pueden encontrar en Puerto Rico y que se pueden identificar en La Esperanza: mangle rojo (*R.mangle)*, mangle blanco *(L. racemosa)* y mangle negro (*A. germinans)*. Para nuestra investigación dividimos nuestra area de estudio en tres zonas principals de muestreo: Zona A, Zona B y Zona C. Se seleccionaron 8 metales (Pb, Se, Cu, Zn, Hg, Cd, As y Cr) para identificarlos, medir sus concentraciones en sedimentos y en hojas verdes y senescentes, con la finalidad de estudiar la capacidad de fitorremediación de las tres especies de manglar como una alternativa de mitigación para metales pesados. Se tomaron 40 muestras de sedimentos (5 en Área A, 5 en Área B y 21 en Área C) utilizando un barreno de acero inoxidable. Las muestras de sedimentos mostraron las siguientes concentraciones por zonas de muestreo (A, B, C): As [3.63, 3.07,4.83], Cd [0.24, 0.06, 0.02], Cr [13.72, 6.73, 5.18], Cu [17.45, 9.62, 4.61], Pb [4.37, 2.18, 0.56], Hg [0.04, 0.01, 0.006], Se [0.00, 0.00, 0.00] and Zn [31.05, 13.88, 7.81]. Se llevó a cabo un análisis estadístico de ANOVA sobre las distribuciones de cada metal entre las 3 zonas, los resultados fueron: valor de p As=0.045, valor de p Cd=0.021 y valor de p de Cr, Cu, Pb, Hg y Zn=0.00. De los resultados obtenidos para sedimentos, se puede establecer que existe un gradiente en la distribución para los 8 metales; siendo la zona A la de mayor concentración de metales y la zona C la de menores concentraciones, con excepción del As que mostró mayor concentracción en la zona C. Posibles explicaciones para esto pueden ser: 1) Diferentes patrones para deposición de metales en los sedimentos, 2) Diferente tasa de absorción por parte de la vegetación, o 3) Una distribución desigual de manglares en las 3 zonas. Para el estudio de las hojas de manglar, se recolectaron un total de 42 muestras de hojas verdes y senescentes (21 para hojas verdes y 21 para hojas senescentes). Se midieron los valores de Retranslocación (RT) y los factores de Bioconcentración (BCF's) para las tres especies. Los resultados sugieren que la especie *A. germinans* puede mover As y Hg hacia las hojas senescentes en mayor cantidad que las otras dos especies. Se obtuvieron valores más altos de RT en las especies de Avicennia y de Rhizophora para Cu en la zona C, lo que puede deberse a una mejor eficiencia de la planta cuando las concentraciones de este metal en el suelo son menores; esto sigue el concepto de eficiencia de nutrientes. Para el Zn, sólo Avicennia demostró un mayor reúso del metal. De este estudio se concluye que las tres especies de manglares tienen diferentes requerimientos de nutrientes, no manejan de forma similar los metales pesados y su capacidad de

fitoextracción pudiera verse afecada cuando las concentraciones de metales en sedimentos son demasiado altas a lo que la planta puede manejar. Esto último sugiere que existe un umbral o punto máximo de cada metal para cada una de las tres especies de maglar, luego que la planta lo alcanza puede disminuir su capacidad como fitorremediador. En el análisis estadístico donde comparamos los diferentes BCF's y valores de RT no obtuvimos diferencia significativa de una especie sobre otra, por lo que se pudo concluir que las tres especies son igualmente importantes en el manejo de estos 8 metales dentro de Península La Esperanza. Este estudio preliminar intenta enfocarse en la importancia de los ecosistemas de manglar en Puerto Rico y a nivel global; ya que sirven de amortiguadores naturales que ayudan a absorber y estabilizar contaminantes dentro de un área, aumentando su importante rol como los mejores protectores dentro de los ecosistemas costeros.

ABSTRACT

Heavy Metals (HM) are naturally present in the environment; however, anthropogenic activities represent the most common factor for major changes in soil HM concentrations. Our study site, Peninsula La Esperanza, is part of the San Juan Bay Estuary Watershed, a Wildlife and Natural Reserve since 2008. One potential method for managing HM in sediments is phytoremediation. The mangroves, which are the predominant type of vegetation in the area, can exhibit diverse external and internal mechanisms that allow them to tolerate and stabilize HM in surrounding soils. This study was focused on three mangrove species in La Esperanza: *R.mangle*, *L. racemosa* and *A. germinans*. For our study we have selected Pb, Se, Cu, Zn, Hg, Cd, As and Cr to be identified, measure concentration in sediments, in Green (GL) and Senescent (SL) leaves, and study phytoremediation potential as a mitigation alternative for these HM. We collected 40 sediment samples in total (5-Area A, 5-Area B and 21 Area C) using a manual stainless steel soil auger. The sediment samples had ppm average concentration of: As [3.63, 3.07,4.83], Cd [0.24, 0.06, 0.02], Cr [13.72, 6.73, 5.18], Cu [17.45, 9.62, 4.61], Pb [4.37, 2.18, 0.56], Hg [0.04, 0.01, 0.006], Se [0.00, 0.00, 0.00] and Zn [31.05, 13.88, 7.81] per sampling area. One-Way ANOVA analysis per metal per area showed: p-value As=0.045, p-value Cd=0.021 and p-value Cr, Cu, Pb, Hg and Zn=0.00. We found a gradient of HM distribution A>B>C, being Area A the closest to urban communities and La Malaria Creek discharge. Possible explanations are (1) different rates of deposition of HM, (2) different rate of bio-absorption or (3) vegetation distribution. A total of 42 samples of leaves were collected in seven major areas around the Peninsula, 21 samples of green leaves (GL) and 21 samples of senescent leaves (SL) from the 3 mangrove species. Bioconcentration factors (BCF's) and Retranslocation Factors (RT) were measured for each species. Results suggest that *A. germinans* moves As and Hg to the senescent leaves more than the other two species, higher RT values of Avicennia and Rhizophora for Cu in Zone C suggest better nutrient efficiency or higher plant needs of this ions when compared with Laguncularia. For Zn, only AG exhibited a reuse of the HM. From our data we concluded that the three mangrove species have different nutrient requirements, they don't manage the HM at the same rate and phytoextraction potential could be limited when the plant reaches certain thresholds of HM in surrounding sediments. Statistical analysis didn't point a species better than other for phytoremediation of these metals. Since we did obtain different value for BCF's and RT values we can conclude the three species used for this study are having a role managing the HM in La Esperanza. This preliminary study aims to contribute to the importance of mangrove conservation and protection in Puerto Rico and globally, as they function as natural buffer zones that can absorb and stabilize pollutants within an area, increasing their already important role as the major natural protectors of the coastal environments.

CHAPTER I

INTRODUCTION

Problem background

Coastal wetlands occur in tropical and subtropical parts of the globe in a range between the latitudes 25° North and 25° South (Lugo & Snedaker, 1974; Miller & Lugo, 2009a), better known as the Tropics of Cancer and Capricorn. Wetland ecosystems have been degraded over the years in many parts of the world and Puerto Rico is not the exception. It is estimated that Puerto Rico may have had around 30,000 acres of mangroves at the time of European discovery and by 1980 up to 75 percent of the mangroves of the island had been altered or destroyed somehow (Miller & Lugo, 2009a).

Wetlands are defined as areas where the soils could be periodically saturated or completely saturated by water in some parts of the year and can sustain hydrophytic vegetation (PR Planning Board, 2008). Coastal marsh vegetation has been adapted to couple with specific levels of salinity, pH, temperature, and poor oxygenated soils (Miller & Lugo, 2009b).

Mangroves are open systems that can be considered as interface ecosystems between upland terrains and coastal estuarine ecosystems (Lugo & Snedaker, 1974). All the anthropogenic activities in upland areas could result in an impact to lowland and estuarine ecosystems (Ayotunde, Offem & Ada, 2011; Pi, Tam & Wong, 2011). Mangroves can also serve as a sinks for pollutants (Lacerda et al., 1988), they can exhibit diverse external and internal mechanisms that help them tolerate heavy metals presence in the surrounding soils. These mechanisms have been studied and documented in different tropical regions of the world (Birch & Olmos, 2008; Garbisu & Alkora, 2003; González-Mendoza, Juárez & Cervantes Díaz, 2008; Jinchung, Chongling, Macnair, Jun & Yuhong, 2006; Machado, Gueiros, Lisboa-Filho & Lacerda, 2005).

Península La Esperanza (Figure 1), our area of study, is a fragmented part of a bigger marsh known as Las Cucharillas Marsh. Aerial pictures (Figure 4) and geological maps (PR Planning Board, 2008) are proof of what was a complete interconnected marsh system that has been subject to many changes over the years. This ecosystem serves as habitat for many aquatic and terrestrial species, and also for estuarine species that are adapted to the specific climate conditions of coastal wetlands (DNER, 2005). Many of the species that use the Cucharillas Marsh are either endangered or vulnerable species (DNER, 2005). Mangroves are also known to help in the prevention of coastal erosion; they can serve as a buffer area to protect the coast from hurricanes and wave energy, among many other functions (Miller & Lugo, 2009a). The border of the Península La Esperanza has a predominant vegetation of three species of mangroves: red mangrove *(Rhyzhopora mangle),* white mangrove *(Laguncularia racemosa)* and black mangrove *(Avicennia germinans).*

Study problem

Heavy metal pollution has been increasing with the development of industries and human sprawl, and it's a current problem in many countries (Azevedo & Rodriguez, 2012). New techniques and restoration practices, like bioremediation and phytoremediation, are being developed and applied for the protection of natural resources impacted by pollution.

Bioremediation is the use of organisms, usually microbes, to clean up contaminated soils, aquifers, sludges, residues, and air (Garbisu & Alkorta, 2003). Plants can also accumulate, extract or serve as bioindicators of pollutants in the soil (Azevedo & Rodriguez, 2012). They can accumulate metals that are essential for growth like Cu, Mn, Fe, Mg and Ni but also other that are not essential for plants such as Cd, Cr, Pb, Co, Ag, Se and Hg (Garbisu & Alkorta, 2003; Lugo, 1998). The process by which plants are used to clean or lower the pollutants in a determined area is known as phytoremediation (EPA, 2012c). The use of different plants is known as a cost-effective method to lower and contain the amount of pollution in a place. This has also been studied with different plants, from small grasses (Hammad, 2011; Mellem, Baijnath & Odhav, 2009) to vascular plants like the mangroves (Defew, Mair & Guzmán, 2005; MacFarlane, 2002; MacFarlane, Koller & Blomberg, 2007; Machado, Silva-Filho, Oliveira & Lacerda, 2002).

Most of the heavy metals are found naturally on Earth and they become toxic when the amounts in soil or water are higher than natural. The amount of naturally found heavy metals can vary from soil to soil and region to region, depending on the geology of the studied area. Since plants cannot move, they can be the first ones to be affected by heavy metal pollution. Some of them, like mangroves, have developed unique mechanisms to deal with stressors through time like for example salinity. Heavy metal pollution is another stressor for which they have developed ways to survive to (González- Mendoza et al., 2008). There have been studies about how mangroves react in soil polluted soils. For example, in Machado et al. (2005), the study discusses how *Rhizhophora mangle* have developed iron plaques in their roots for the exclusion of Fe, Mn and Zn from the organism. Similar recent studies of iron plaque in mangrove roots have been assessed with other species of mangroves; in Pi et al. (2011) controlled experiment, they irrigated the mangroves with wastewater through different periods of time and concluded that root surface increased with wastewater discharge, and the iron plaque formation was immobilizing Ni, Pb, Cr and P more effectively than Cd, Zn, Mn and Cu. A recent study of Da Souza et al. (2014) in South America concluded that the species *Laguncularia racemosa* has certain plasticity in the roots, showed by larger root ratio in areas more polluted. Most of the information for mangroves available is related to how they use essential nutrients such as Nitrogen, Phosphorus and Potassium, and their role in bioconcentrating and retranslocating them through the plant (Lugo, 1998). However, more information is necessary on how they behave bioconcentrating and retranslocating heavy metals on polluted soils.

Retranslocation (RT %) is a measure from the nutrient use-efficiency concept that measures the amount of nutrients that are re-absorbed by the plant before leaf fall (Lugo, 1998). Usually if the soil is deficient in a basic nutrient needed for plant growth, the plant becomes more efficient in the use of this nutrient, recycling it before losing it in the leaves. In a recent study from different researchers in Jobos Bay (Lugo, Medina, Cuevas, Cintrón, Laboy Nieves & Novelli, 2007) they calculated the retranslocation of Nitrogen (N) and Phosphorus (P) and compared the rates from the three different mangrove species of our interest *Laguncularia racemosa*, *Avicennia germinans* and *Rhizhophora mangle*; the trend for retranslocation of N and P was as follow: *Avicennia* > *Rhizhopora* > *Laguncularia.*

Bioconcentration concept as defined by the US Geological Survey (2011) is the "biological sequestering of a substance at a higher concentration than that at which it occurs in the surrounding environment or medium". Plants can accumulate heavy metals in different part of their organism (shoot, stem, roots, and leaves) at different rates. Is when bioaccumulation on the leaves occurs that there is a higher chance of transporting heavy metals to the surrounding environment and a higher chance for heavy metals to enter the trophic chain.

In previous research efforts at Península La Esperanza (Mejias, Musa & Otero, 2013), sediment-sampling results revealed heavy metal contamination in this area. Other research projects done in surrounding areas of the Peninsula, such as the UMET Research area (close to Bacardi Industry in

Figure 2), have obtained data of pollution in soils and water (Román, 2010; Marengo, 2008). In the Mejias et al. (2013), the researchers collected scattered sediment samples. The study showed that several heavy metal concentrations were above the baseline parameters from Florida (Chen, Ma & Harris, 1999), which they use to compare their sediment concentration results. The researchers also evaluated and compared the phytoremediation capacity of the black mangrove (*Avicennia germinans)*, the white mangrove (*Laguncularia racemosa)* and the red mangrove *(Rhizhophora mangle)* in the heavy metal polluted soils. They calculated bioconcentration and retranslocation factors from senescent and green leaves, concluding that *Avicennia* sp. was concentrating more heavy metals in its senescent leaves, therefore it could be posing a major threat in exporting the metals to the surrounding environment.

This study is a continuation of a project that began in 2012 under the same federal grant. It was focused in the collection of a larger amount of sediments samples (4o samples) from near mangrove populated areas in three different zones of Peninsula La Esperanza (Figure 2). The three species of mangroves predominant in the area are: *R. mangle, A. germinans* and *L. racemosa* (red, black and white mangroves) were sampled for leaves (42 samples) to determine the concentration of metals in this part of vegetative tissue. The sediment samples and the leaves taken were used for the assessment of eight heavy metals (Pb, Se, Cu, Zn, Hg, Cd, As and Cr) using ICP technology and establishing, through mathematical formulas and different statistical analyses, if there was a relationship on how mangroves bioconcentrate and retranslocate these eight metals.

Problem justification

The Cucharillas Marsh was a very broad wetland ecosystem interconnected with the Bayamón River, the San Juan Estuary and the open Atlantic Ocean. Over the years there has been strong urban development in this area and a significant amount of marsh was dredged and filled by the US Corp of Engineers in the early 1950's. This event was an important factor that provoked drastic changes in the coastal marsh, fragmenting it, and changing the natural hydrological patterns of the region. Many poor or low income communities settled around the marsh terrains. The area is a recreation center for many people from inside and outside the community, as well as a fishermen village. The interconnectivity with the rest of the San Juan Bay Estuary makes this place a unique place in the middle of the metropolitan area but also a target from many pointed and non-point sources.

There have been several mangrove studies in Puerto Rico and other parts of the world related to the behavior of these trees in heavy metal polluted soils and waters (Aldarondo-Torres, Samara, Mansilla-Rivera, Aga & Rodriguez Sierra, 2010; Machado et al. 2002; Seguinot, 2002). Nevertheless, these studies are almost always focused in one part of the plant, and not in different parts of the trees at the same time. In other studies, several parts of the plant have been studied at the same time, but not for heavy metal contamination data (Lugo et al., 2007).

The conservation of Peninsula La Esperanza mangrove ecosystem is important for several reasons. First, it is very close to the ocean which provides a buffered area that protects the industrial and urban activities along the coast. Second, it serves as a nursery for the completion of the life cycle of fishes before they can enter the open Atlantic Ocean, and also serves as a pollutant filter and sink. Third, it helps to protect the sandy shore from erosion and wave energy impacts, not to mention from hurricane season. Last and most important reason, for the need of more data for pollution levels of the area because this ecosystem is very close to human communities. For the reasons mentioned, we want to assess this study with the finality of obtaining a broader perspective of the level of heavy metal pollution in this area. The results of this study can later be used in the development of better management strategies for the Las Cucharillas Marsh Natural Reserve. At the ecological level, the mangrove population at this study site could represent a highly important asset to the coast due to its close vicinity to the urban areas and the protection it brings to them. Therefore, having a healthy and aesthetically well preserved ecological system could be of high benefit for the community and public recreation areas nearby, as well as for the trophic chains sustained by it. We aim that this study will serve as an important contribution to the mangrove ecosystem data of Puerto Rico, and also as a reference for further phytoremediation studies.

Research questions

What is the concentration of As, Hg, Cu, Zn, Cr, Cd, Se and Pb on the sediments from Peninsula La Esperanza and what relationship could exist with the phytoremediation potential of the three species of mangroves in the area?

Goals and Objectives

Goals*:* Assessment of heavy metal concentration in mangrove sediments from Las Cucharillas Marsh Natural Reserve. (Peninsula La Esperanza)

Objectives:

- Increase the amount of mangrove sediment samples from previous research efforts (Mejias, Musa & Otero, 2013) to evaluate the significance of the heavy metals presence in the mangrove ecosystem.

- Determine Retranslocation (RT) values (Lin & Wang, 2001) in senescent and green leaves from 3 species mangroves in Peninsula La Esperanza to know how much HM mangroves can manage.
- Determine Bioconcentration Factors (BCF's) (Mellem, Baijnath & Odhav, 2009) using the sediment and leaves data analysis to know the concentrations of HM the trees are absorbing.
- Statistical Analysis of all the parameters to assess the heavy metal concentrations in La Esperanza and determine the capacity of mangroves to deal with heavy metal presence.
- Establish recommendations to manage HM presence in La Esperanza.

CHAPTER II

LITERATURE REVIEW

Historic background

The Cucharillas Marsh Natural Reserve (CMNR) is located in the municipality of Cataño, which is surrounded by the municipalities of Bayamón, Toa Baja and Guaynabo (Figure 1). The CMNR is considered one of the biggest fresh water marshes on the island, and the biggest mangrove area of the north part of the P.R. (Miller & Lugo, 2009a). There are many communities surrounding this marsh: Las Cucharillas, Juana Matos, Puente Blanco, and Reparto Paraíso.

The municipality of Cataño is part of the geographic region of the coastal valleys of the North. These valleys receive a mean precipitation of 80 inches; at the Cucharillas Marsh the mean precipitation fluctuates from 60”- 80” being lower in the months of draught from Feb-Apr. The mean temperature for the area can reach a maximum of 27.4° C and a minimum of 23° C, as stated on the Declaration of Environmental Impact Document from the PR Planning Board (2008).

The Peninsula La Esperanza as well as the rest of the Las Cucharillas Marsh is part of the San Juan Bay Estuary Watershed. It is a unique tropical estuary in the National Estuary Program of the US Environmental Protection Agency. In 1979, the Department of Natural and Environmental Resources (DNER) designated part of the Marsh as a wildlife reserve. Later in 2008, the Puerto Rico Planning Board in a joint effort with the DNER designated the Las Cucharillas Marsh a Natural Reserve (PR Planning Board, 2008). It has about 1,236 acres (500 hectares) from which 10 of the acres were donated to the Universidad Metropolitana by the Bacardi Industry for scientific research (USEPA, 2004).

The CMNR has been impacted through the years. It was used as a clandestine dumpsite, dredged and filled by the US Corp of Engineers in 1951, and the rivers adjacent to it have been channelized (Román, 2010). In 1994, the Bacardi Industry discharged used waters into the marsh (USEPA, 2004). Later on 2009, some of the CAPECO tanks located inside the marshland from the GULF oil refinery exploded (Román, 2010). All these events, among others, have influenced on the gradual deterioration of the natural ecosystem.

Part of the Peninsula is considered a man-made piece of land (Figure 3). There is a current berm of sand that is slowly closing the entrance of salt water into the Peninsula and several mangroves (Figure 4), specially white and red mangroves can be seen growing in the area. La Malaria Creek discharges its water on the Peninsula. This creek (Appendix 3) has affluent waters from Aguas Frías, The Bayamón River and the San Fernando channel (Román, 2010), and it could represent some of the sources of contamination brought from upland terrains to the ocean. In previous studies (Mejias et al., 2013), Península La Esperanza soils (Figure 3) have been surveyed in three different areas including the one closest to the Malaria Creek; results showed that this area could be one of the biggest threats to the mangroves. The marsh is used by many species of birds that can be seen from the shore and the fact that these mangroves are acting as a sink for trash and pollutants, it could pose a risk to the flora and fauna communities.

Theoretical framework

Mangroves have several special adaptations to survive on saline environments. They can tolerate high levels of salinity, have specialized roots that anchor them to unstable soils, have viviparous seedlings, and they have other adaptations like pneumatophores necessary for gas exchange with the atmosphere (Miller & Lugo, 2009a). The use of vivipary seeds and prop roots such as the ones in red mangrove (*R. mangle)* species. This is one of odd species that have demonstrated to have a seed attached until is full grown, falls and then travel across in watery mediums until it finds sediment good enough to settle and grow. (Miller & Lugo, 2009a) The prop roots help in the anchorage of the tree to unstable soils, this also helps in prevent erosion. The high salinity adaptation is better represented by the black mangrove or *A. germinans.* This mangrove usually grows farther away from water and their leaves have a mechanism of salt exclusion. Also, they have developed pneumatophores, where gas exchange takes place with the atmosphere. The white mangrove or *L. racemosa* is the one that usually populates first a clear area to be followed by the red mangrove. They also have other species of plants that grow attached or near them, which help in the availability of nutrients in the soils close to the mangroves (Rodriguez & Stoner, 1990). They produce a high amount of litterfall which is quickly degraded mainly by bacteria helping to fix nutrients to the soils such as Nitrogen, Sulfur and Phosphorous (Gadd & Griffiths, 1978). The bacterial community associated with this type of soils has been underestimated. A type of acterial community, known as archael bacteria, can survive in anoxic and high salinity soils where other organisms couldn't survive. For soils with heavy metal pollution, there are some species of bacteria that can act as bioindicators of this type of contaminants (Angle, Chaney & Rhee, 1993; Gadd & Griffiths, 1978).

Puerto Rico has four main species of mangroves, which are: *Rizhophora mangle* (red mangrove), *Avicennia germinans* (black mangrove), *Laguncularia racemosa* (white mangrove) and *Conocarpus erectus* (buttomwood mangrove). Mangroves are obligatory or facultative vegetation for marshes and estuarine areas, they have developed special adaptations to survive in these interface regions (González-Mendoza et al., 2008). Mangrove forests in the island can be divided in 4 types, which are: Fringe forest, Riverine forest, Overwash forest, and Basin forest. There are several publications that discuss the characteristics of mangroves (Lugo, 1998; Miller & Lugo, 2009a) and their zonation and physiognomy (Lugo & Snedaker, 1974). Several research studies have been done in different mangrove forests of the island (Lugo et al., 2007; Mejias et al., 2013; Seguinot, 2002).

Present studies are focused toward the study of how several ecosystems can serve as carbon dioxide sinks and the effects this could have at a global scale on the context of climate change. The blue carbon is carbon captured by world's oceans and stored in marine organisms from carbon dissolved in water, a process done by mangroves, seagrasses, marshes and algae; this stored carbon can then be released as CO^2 upon natural death, degradation or use for products (Nellemann, Corcoran, Duarte, Valdés, de Young, Fonseca & Grimsditch, 2009). The process by which this ecosystem store carbon is known as carbon sequestration (Chopra, Leemans, Kumar & Simons, 2005). Salt marshes followed by mangroves and seagrasses are the marine habitats with more capacity to serve as carbon sinks (Nellemann et al., 2009).

Soils

Soils have four major components, which are: mineral matter, organic matter, air and water (NRCS, 2006). Wetlands have a very high amount of organic matter. Organic matter contains quantities of nitrogen, phosphorus, and sulfur (NRCS, 2006) that are needed for plant growth and development.

For this research study, the area of Península La Esperanza was divided into three sampling zones, which are zone A, B and C (Figure 2). There is variability on the type of soils of the Peninsula as shown on the NRCS maps. The site A is composed mostly hydric soils (Hy) and silty fines (SM). Hydric soils are formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper parts (USDA-NRCS, 2012a). The material under these soils could be clay or sand; they present halophytic vegetation, like for example mangroves (PR Planning Board, 2008). The site B is composed mostly of Hydric soils, and the site C is composed of what is called Md soils; Md soils are defined as man-made soils and it is in fact a man-made piece of land (USDA-NRCS, 2012b). These types of soils and their distribution are illustrated in Figure 3.

Heavy metals

The heavy metals have a density 5 times larger than water (Ayotunde et al., 2011). Binding of metals to organic materials, precipitation, complexation, and ionic interactions are all important phenomena to be considered when studying heavy metals on the field (Gadd & Griffiths, 1978). One of the definitions of heavy metals is an element that has metallic properties such as ductility, conductivity, density, stability as cations, ligans specificity, and an atomic number greater than 20 (Garbisu & Alkorta, 2003). Soil metal concentration in the natural environment mainly depends on geological and mineralogical characteristics of the parent material, whereas in the urban environment it is also affected by dry and wet deposition of metals emitted by human activities or transported from the surroundings (Maisto, Manzo, De Nicola, Carotenuto, Rocco & Alfani, 2011). There are some issues about the name of heavy metals versus trace metals. Current studies use the wording heavy metals when they refer to metals that can be toxic to environment or human beings. Usually trace metals are elements that can be used by living organisms in certain amounts such as Chromium and Copper; both of them are needed for the enzymatic processes, while other like Mercury, have no known uses for organisms and are highly toxic. For our study we will use the wording heavy metals since all of the eight metals studied have known consequences if living organisms are exposed to them.

Availability of metals is more complicated that it seems. Detailed studies are required to measure the availability of trace metals from the surrounding soils. Soil conditions including pH, salinity and pore water could be factors of the form of the type of metal ions available for uptake. These are some of the soil parameters affecting the bioavailability of the heavy metal. The primary soil factor controlling the potential bioavailability of all contaminants are pH, available charged sites on soil surfaces, clay content, and soil organic matter (USEPA, 2005). The Guidance for Developing Ecological Soil Screening Levels from the USEPA establishes the cationic species in which different metals can be found. It also explains that metals can complex with other soil constituents such as: carbonates, sulfates, hydroxides and sulfides to form different compounds. Metals in their various forms can exist in the pore water as charged species, as soluble complexes, or precipitates out of solution. The pore water is known as the molecules of water in the interstitial spaces of the soil. The type of soil, thus, will affect in the availability of this metals for plant uptake. Doing what is called a soil profile can help in understanding how the heavy metals are located through the soil and which ones are more available to plant uptake (Jingchun et al, 2006; Birch & Olmos, 2008). The Eco-SSL study from the USEPA (2005) provides more information about heavy metals and in which way they are available in nature depending on their ionic form.

The soil sampling in our study will assess the concentrations of eight heavy metals in the sediments from Peninsula La Esperanza. The heavy metals to be studied are:

Arsenic

Arsenic, organic and inorganic, is a naturally occurring element found throughout the environment and it naturally occurs from the earth's crust. It is considered very toxic to human health. The inorganic arsenic is more common to be found in areas closer to volcano activity, where there is weathering of arsenic-containing minerals and from commercial or industrial processes (USEPA, 2000a). When combined to Oxygen, Chlorine and Sulfur it forms inorganic compounds. Arsenic is usually used as pesticides, as a feed additive for poultry and swine and in cattle to control lice and ticks. It is used in alloys and in semiconductors.

Arsenites especially can be very mobile through the soil pores. The typical ratio concentration in plants to that in soil is low, estimated at 0.006 (or 0.6 %).

Cadmium

Cadmium is another metal found naturally on the earth's crust. It can form compounds with other elements such as Oxygen, Chloride and Sulfur; which are also commonly found in the environment. It is a by-product of the process of Zinc or Lead melting or in the process of making batteries, pigments and plastics. Other source of Cd pollution could be the burning of fossil fuels like coal or oil or burning of municipal wastes **(**USEPA, 2012a). This element can be transmitted through air, water or through eating poisoned food.

Chromium

Chromium occurs in the environment in the form of Cr trivalent and hexavalent Cr. The first one is considered less toxic than the second one. Chromium trivalent is an essential element in humans (USEPA, 2000b).

Copper

Unlike other heavy metals, such as Cadmium, Lead, and Mercury, Copper is not readily bioaccumulated and thus its toxicity to man and other mammals is relatively low; on the contrary, plants in general are very sensitive to Cu toxicity, displaying metabolic disturbances and growth inhibition at Cu contents in the tissues only slightly higher than the normal levels (Fernades & Henriques, 1991). Copper exhibits a reduced motility in soil and sediments but in aqueous media plants can be more susceptible to Cu contamination (Fernandes & Henriques, 1991).

Lead

Lead is also found naturally in the environment in small amounts but it is very toxic to human health. Lead is widely used in different products including paint, ceramics, pipes and plumbing materials, gasoline, batteries, ammunition, and cosmetics (USEPA, 2012).

One of the causes of soil contamination with Lead is the gasoline from cars and the industrial sources. Our study site is very close to different types of industries including rum and oil refineries and also has been highly impacted by excessive human activities.

Mercury

Mercury is one of the more toxic metals to human health. Mercury in the air can settle into water or onto land where it can be washed into water. Afterward, it can be methylated by microorganisms and more available for fishes, shellfishes and other animals that feed on fish (USEPA, 2013). Other studies have explained in more detail the cycle of Mercury in the environment and the change from inorganic to organic and therefore more available for organisms (Azevedo & Rodriguez, 2012).

Selenium and Zinc

Selenium is another natural occurring element that in high concentrations can be very toxic but it is also a nutritionally essential element. It is used in a variety of industries and is also used for agriculture and as a fungicide (USEPA, 2000c; International Zinc Association, 2011).

Case Studies

1. *Baseline concentrations of 15 trace metals in Florida surface soils*

In the Chen, Ma and Harris (1999) study the researchers established the baseline concentration for Ag, As, Be, Cd, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Sb, Se, and Zn for the soils of Florida. They also studied soil properties including pH, organic carbon, particle size, cation exchange, available water, extractable base and acid, among other parameters. Our study aimed to provide more information because no federal regulation specifies maximum metal concentration in non-hazardous wastes for land application except for sewage sludge. It is important to establish background concentrations of trace metals for soils within a specific region. They studied almost 500 surface soils horizons. They define geochemical baseline concentration as an expected range of element concentration around a mean in a normal sample medium. They also compared Florida soils with other data from other parts of the world. In the proposed study we will use this data to establish comparisons with the data collected from our research. This comparison has its limitations beginning with the soil differences between the soils of Puerto Rico and Florida. Since there is a lack of information about the natural metal concentrations in the island, the extense study of Florida at least can serve as a point of reference.

2. *Trace metals, PAHs, and PCBs in sediments from the Jobos Bay area in Puerto Rico*

Jobos a Natural Reserve and La Parguera are located in the southern region of the island. Aldarondo-Torres, Samara, Mansilla-Rivera, Aga and Rodríguez-Sierra (2010) research established 14 stations in Jobos and 5 stations in La Parguera. Both areas are populated with mangroves. They studied As, Cd, Cu, Pb, Zn, Fe, and other organic compounds that could be toxic for these ecosystems and surrounding areas. They used an equation for metal enrichment factor (MEF) to differentiate natural contribution from anthropogenic contributions of these trace metals in the soils. They compared both areas with each other and also with other data from the Caribbean region. They concluded that Jobos Bay Natural Reserve had higher concentration of heavy metals than the ones from La Parguera.

3. *Exploratory Evaluation of Retranslocation and Bioconcentration Efficiency of Heavy Metals in Three Species of Mangroves at Las Cucharillas Marsh, Puerto Rico*

In the study of Mejias et al. (2013), the researchers took several samples from the same coastal zone of this study proposal. They analyzed data for 10 metals: Hg, Al, As, Cd, Cr, Cu, Fe, Pb, Mg, Zn. They focus their study in three specific types of mangroves: red, black and white. Most of the research was done with the leaves from which they calculated the amount of heavy metals to make a comparison of heavy metal concentrations in new and senescent leaves from each one of the species. The researchers concluded that the 3 species where reacting different in the use of heavy metals. Even though the soil samples were scarce for this study, the concentration on the leaves can give a preview of the chemical conditions of the available sediments for the mangroves. The conclusions for this study was that *Avicennia germinans* (black mangrove) showed higher concentration of heavy metals in its senescent leaves when compared to the other species *Laguncularia racemosa* and *Rhizhopora mangle*. Heavy metals on the leaves are available through suction from of nutrients or heavy metals from the soil through the xylem and the phloem of the tree eventually stored in the leaves. This species seems to be exporting concentrating contaminants in the leaves (leaves serve as storing part of the plant) and could be exporting them to the rest of the ecosystem. Further studies to measure the amount of contaminant in different parts of the plants and comparing the results among different mangrove species could be done to better understand these mechanisms of heavy metal usage. The researchers concluded that *Avicennia* sp. was a poor phytoremediator because it has a low Retranslocation (RT) value; therefore, transporting heavy metals through its senescent leaves to the litterfall and to other organisms that feed on them.

4. *Trace metal retention in mangrove ecosystems in Guanabara Bay, SE Brazil*

In the study of Machado, Silva-Filho, Oliveira and Lacerda (2002) they focused their research in how *Laguncularia racemosa* was using the Zn, Pb, Cu, Ni, Mn in the Guanabara Bay. For the study they established different station for which they measure leaf concentration and potentially available metal concentrations in the mangrove sediments. They used (CF) concentration factors to measure the amount of metals transferred from sediments to leaves. The researchers concluded that there was a low transfer of sediment bound metals to the leaves for *Laguncularia racemosa.*

5. *Accumulation and partitioning of heavy metals in mangroves: A synthesis of field based studies*

In this study by MacFarlane, Koller and Blomberg they collected information about Cu, Pb, and Zn concentrations in different species of mangroves. They found that the BCF's in root tissue were higher than the ones found for the leaves. When comparing the BCF's in roots and leafs they concluded that the essential elements like Zn and Cu showed a greater mobility than non-essential elements like Pb, which was excluded by the plant through the leaf.

Legal framework

There are different laws that have been established on the island for the protection of mangroves. Since P.R. is a Commonwealth U.S. territory both state and federal laws apply in this matter. Some of the laws that can be mentioned related to the mangrove protection are:

State Laws

-"Ley de Tierras", Law 314, December 24, 1998, S.E

-Law 150, "Ley de Programa de Patrimonio Natural", August 4, 1988.

- PR Planning Board and DNER declared the Las Cucharillas Marsh a Natural Reserve (2008)

Federal Laws

-Clean Water Act, section 404

-Resource Conservation and Recovery Act

-Emergency Wetlands Resource Act

-Coastal Zone Management Act, 1972

CHAPTER III

METHODOLOGY

Study Area

The Península La Esperanza is located in the coordinates 18°27'06.28" N and 66°08'07.09" W (Figure 1). It is part of the Cucharillas Marsh and the San Juan Bay Estuary. For our research, we have divided the Study Site into three sampling zones or sites (Figure 2). The sampling site A (18°26'. 980" N, 66°08'. 203" W) borders the coast and it is located right in front of private houses. The area of the site A is approximately 19,199 m^2, and it has a few patches of mangroves along the border. The sampling site B (18°27'.270" N, 66°08'.032" W) is located inside a recreation area known as the Esperanza Park. This park borders the Bacardi refinery on its West side and faces the Atlantic Ocean on its North side. The mangrove population in this part is very scarce until it reaches the point of the Peninsula where most of the mangroves are population the area. The predominant species in the area are red and white mangrove. It has an area of approximately 46,959 m^2. The sampling site C is located at the coordinates (°27'. 012" N, 66°07'. 851" W) and it has an approximated area of 55,223 m^2. This part of the Peninsula (Figure 2) is separated from the rest of the land. Sampling site C is completed surrounded by ocean water. Part of this sampling site is fully populated by *Casuarina equisetifolia* (Australian pine) and no mangrove population could be seen inside the understory. Even though it could be considered a little island, the vegetation in the middle is very dense making it harder to take the samples at the inside of the isle. There is a section where a mature red mangrove area is located. Along the borders, especially the border facing the San Juan Bay, black mangrove population can be found. A high percentage of this area is covered in trash from all types. Most, if not all of this area has an elevation under the sea level.

Sample description and Analysis

The sediment samples were collected with a stainless steel manual auger, the first inches were discarded and the rest of the sediment stored in a glass container, then in a cooler, and finally the samples were taken for analysis to a private laboratory in San Juan area named Sanco, which is certified by the US Environmental protection Agency (EPA). Gloves were used at all times for avoiding physical contact with the sediments. Also glasses for protection of the face area, boots, and hat for sun exposure protection.

The mangrove leaves were collected by hand. Latex gloves were used to avoid direct contact with the leaves. The leaves were selected from mature mangrove trees at the height of the chest. The three mangrove species sampled were: *Avicennia germinans, Laguncularia racemosa* and *Rhyzophora mangle.* All the leaves samples were stored in plastic bags, stored in cooler and then taken to Sanco to perform the analysis of the sediments.

The Sanco laboratory used the method EPA 6010C for Arsenic, Cadmium, Chromium, Copper, Lead, Selenium, and Zinc. For Mercury analysis, the laboratory used method EPA 7471B. Sanco Laboratory has all the standards and regulations in place for use, handling and disposal of substances according to the local and federal agencies. Once the results were received, we began a statistical analysis for determining Bioconcentration Factors and Retranslocation Values for each one of the 3 mangrove species.

Data Evaluation

Several statistical analyses were performed including t-test and ANOVA using the Minitab 14 program to establish comparisons among the different areas sampled and to analyze the relationship between heavy metals found on sediments and heavy metals on leaves. Retranslocation (RT) and Bioaccumulation factors (BCF) were calculated and used in the statistical analysis as well.

Since most of the available information for heavy metal pollution refers to sewage sludge and for Superfund Sites (USEPA, 2005), on our study we used the Florida baseline for soils from the study of Chen et al. (1999); the same baseline that was used in previous study from Mejias et al. (2013) for Peninsula La Esperanza.

For the calculations of Bioconcentration and Retranslocation Factor we used the following formulas:

Formula 1:

$$BCFg = \frac{[HMGreenLeaves]}{[HMSoil]}$$

$$BCFs = \frac{[HMSenescentLeaves]}{[HMSoil]}$$

Hammad, 2011; MacFarlane, G.R.; Koller, C.E. & Blomberg, S.P., 2007; Mellem et al., 2009; Miao, S; g, Chen; R, De Laune;A, Jugsujinda, 2007.

Formula 2:

$$\%RT = \left(1 - \frac{[HMsenescent]}{[HMgreen]}\right) * 100$$

Allison & Vitousek, 2004; Hammad, 2011; Mellem et al. 2009

CHAPTER IV: RESULTS AND DISCUSSION

Soil Analysis and Mangrove Distribution

A total of 40 core samples were used for analysis (Figure 5). When the amounts of metals in the three zones were compared (Figure 8 and 9), difference in the distribution of the eight metals in each of the three areas and among areas was found. None of the samples analyzed detected Selenium but it is important to mention that previous studies in the area have detected certain Selenium levels in sediments and organisms, but for this project we removed Selenium from the analysis. The Zn, Hg, Pb, Cu, Cr and Cd concentrations were higher for Zone A (Figure 8) shown in red (which is the area closer to the communities), followed by Zone B, which is the part adjacent to the Bacardi factory and to the Recreational Park. The Zone C demonstrated the lowest concentrations of all the metals in the sediment except for As, which was almost 2ppm higher than Area B and 1 ppm higher than Zone A. The highest mean value was for the metal Zinc (31.05 in Area A) and the lowest mean value was for Mercury (0.006308 in Area C). The order of amount concentration of the HM from high to low in the 3 areas is Zn > Cu > Cr > As > Pb > Cd > Hg > Se. From this pattern of distribution, we can infer that a gradient in the distribution of heavy metals could exist following the pattern A>B>C. Some of the possible variables for this gradient could be: different rates of heavy metal deposition in each zone, different types of mangrove distribution, and different bio-absorption rates.

The bio-absorption of plants is influenced by several factors inside and outside the plant. For a heavy metal or ions of heavy metals to be ready for plant absorption via roots, phloem and xylem; there could be several biotic and abiotic factors at the chemical level that should be included and analyzed in a study. Some of these could be:

a) The type and quantity of organic material,

b) The type and porosity of the soils,

c) The pH levels,

d) Water currents and the fact that some of the areas with highest amount of HM in sediments are areas were there is poor circulation of water. (Some “hot spots” of pollution were identified from our study and other studies are in progress using these data as a starting point)

e) The temperature of the soil,

f) The amount of time the roots of the mangroves are underwater or the cycles in the waves,

g) The adjacent vegetation around the mangroves,

h) The seasonal changes in rainfall

i) Bacterial communities in the sediments- there is very few information about the importance and function of bacteria in mangrove sediments but they might be playing a big role in making the ions available for plant uptake.

j) Some isolated but major pollution events such as the explosion of the CAPECO tanks from the oil refinery in Cataño several years ago.

k) Each mangrove type might have a different internal mechanism for dealing with HM presence that was not assessed in this study.

Using Minitab 14 a One Way Anova test was performed for sediment analysis. When comparing the distribution of heavy metals inside each sampling zone, the p values obtained were less than 0.00 (Figure 8). When comparing the distribution of each heavy metal among the three sampling zones the p-values were As= p value 0.045, Cd =p value 0.021, All others gave a p value= 0. These results showed that the distribution of the 7 heavy metals appears to be different and there is a statistical significance in their distributions. One could expect for example that an area that was dredge and the sediments move from Zone A to Zone C in the past revealed higher HM concentrations in the Zone C, which is not the case we are seeing from our data. This Zone C is the area with the highest amount, biggest mangroves when compared with the other two zones. Zone A and Zone B might be the ones suffering from highest development, but Zone C is serving as a sink for all the trash that the currents bring from other places of the San Juan Bay Estuary.

Since very limited or none information about the baseline values of metals in soils of Puerto Rico is available; we used the Florida's baseline values established by the work of Chen, Ma & Harris (1999) as a point of reference for Peninsula La Esperanza (Table 2). When comparing with Florida's baseline data all of our values were above the minimum levels. Cd, Cu, Hg had mean values very close to reaching the maximum values of Florida's baseline range. In the case of Zinc, Zone A showed a higher mean of 31.05 ppm compared to a maximum value of 29.6 ppm for Florida (Figure 7).

The soil samples taken in 2012 (Table 3) in Area A showed more concentration of Cd than the ones taken this year. This Zone showed very high concentrations of Zn with one of the points (A2 and A4) detecting 47 and 53 ppm respectively. These high Zn concentrations could be entering the Peninsula via La Malaria Creek (Appendix 3), and different sources of pollution caused by non-pointed inland sources. The pollution with Hg, could be coming from the same Creek by its water currents. In the work of Azevedo and Rodriguez (2012) they explained graphically the cycle of Hg and how industries could be the major's sources of inorganic Hg which then deposits in the sediments and becomes available to other organisms via methylation of Mercury. This heavy metal is highly toxic for organisms and humans, and is of major concern for public health due to the high use of recreation and fishing activities at the Peninsula. From all the 8 points sampled for Zone A (2 points showed high amounts (A4 and A5), detecting 0.055 and 0.059 ppm of Hg respectively. The standard limit established by USEPA for potable water of this metal is 0.02 ppm; this can give us another point of reference of the importance of monitoring and lowering the levels of Hg in La Esperanza and performing further studies involving pollutants in this and other natural reserves around the islands of Puerto Rico.

In Zone B all the samples showed Pb concentrations with the highest point being (B3C) with 4.42 ppm (Table 4 and Figure 5). Mercury was also detected in 4 out of the 8 total samples taken around the Recreational Park of La Esperanza and close to the Bacardi Industry (Figure 2).

Leave Analysis, BCF's and RT percents

The data obtained from the laboratory analysis (Appendix 1) showed different levels of heavy metals in green and senescent leaves for the 3 species under study. Tables 6, 7 and 8 show the concentrations for zones A, B and C. Selenium was not found in our leaves study. From the other 7 metals under study the highest quantities we found were for Cu and Zn. Plants for enzymatic processes use these two elements. From our results we can conclude that the three species use Cu and Zn in different amounts. Bioconcentration Factors (Figures 12, 15 and 18) show different percent when comparing green and senescent leaves of each of the species. Our statistical analysis for BCF's didn't show significance in one species over the other in terms of one species being better bio concentrator of HM than other. The RT percents obtained (Table 15) also showed very different values for the three species. A positive RT value means that the mangrove tree is moving the HM from the senescent leave to other tissue, reusing the element. This is based on the Nutrient

Use Efficiency theory (NUE) that when the soils are poor in one element the plant has to be more efficient in the use of that element. A negative RT percent on the other hand, means that the tree is not moving the element and it moved it through the vascular system, it was stored on the leaves and the plant does not need to reuse it. In Figures 13, 14 and 15 an interesting pattern is seen with *A. germinans* for Mercury. The statistical analysis for the RT values in the three areas showed significance when comparing the amount of metals in green leaves and senescent leaves. This means that there is a statistical difference in how the three mangroves move the metals through the plant.

Limitations of the study

Certainly there were some limitations in the study. Since PR lacks of baseline information for soils, the Florida baseline helped as a reference for our results. Also a broader amount of mangroves might have given more results that could help us to have a more specific answer of which species is better phytoremediation which heavy metal. From the literature revision about mangroves as potential phytoremediators, all of the authors have had similar results when studying other parts of the tree such as roots and branches. The lowest concentrations of metals are expected to be in the leaves and higher concentrations are expected to be in the roots. To measure effective Translocation Values of the plant, samples from roots, branches and leaves can give more information.

CHAPTER V: CONCLUSIONS AND RECOMMENDATIONS

If compared with the Florida baseline, the sediment concentration values for La Esperanza are inside the levels for Florida except for Zn which was higher that the maximum level. The sediment data suggests that there is a gradient in the concentrations of Heavy Metals in the Peninsula following a trend of A>B>C. Anthropogenic impacts could be the highest factor for this as area A is the most urbanized.

For the RT values calculated only Hg demonstrated a trend in the 3 areas, to be more excreted by *A. germinans* in leaves. Trophic contamination cannot be determinate by this data. This species also appears to reuse more Zn. For the concentration in leaves, laboratory analysis showed higher levels in leaves for Cu and Zn for the three species.

These mechanisms of how mangroves deal with heavy metal presence and their capacity of phytoremediation are not readily understood and more information about how they react to heavy metals is needed.

Recommendations

Some of the recommendations that can be suggested taking in consideration the results of this research are:

- Follow a reforestation plan that includes the 3 species of mangroves, following the coastal line, and taking into consideration the natural succession of the three species.
- It is highly desirable performing a broader assessment for Mercury levels. The species *A. germinans* showed lower RT levels for the three zones and higher concentrations of

Hg in its senescent leaves compared with the other two species. The fact that the black mangrove appears to be moving Hg faster than the other species to upper tissue such as leaves, it cannot be infer from this that other organisms are being affected by the exporting of this metal to adjacent sediments or water. Further and more specific analysis with black mangrove and other organisms should be performed to study if there could be a relationship between the two factors. Better monitoring of the La Maria Creek is highly desirable due to the fact that this water current might be depositing quantities of HM in the estuary zone. This can be inferring by the high concentration of HM found in zone A compared with the other two sampling areas.

- Establish long term plots in the area. The coastal zones are very dynamic and change quickly over short periods of time. The study of mangroves could be very useful to understand sea level rise, pollution (they can serve as bioindicators of contaminants), carbon storage, and climate change.
- The Cucharillas Marsh is a Natural Reserve that serves, as habitat for resident and migratory birds, among many other species; a continuous control of the amount of trash is critical to maintain a healthy ecosystem. (Especially in the zone C that constantly receives all the trash from water currents)

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TABLES

Table 1

*Minimum in Calibration Curves given by SANCO EPA licensed laboratory for detection of Heavy Metals on sediments using ICP technology. **Values below this minimum are not detected by the equipment. Used for soil samples taken in 2012.*

Heavy Metal	**Calibration Curve Minimum (mg/Kg)**
Arsenic	0.862
Cadmium	0.431
Chromium	0.862
Copper	0.862
Lead	0.431
Mercury	0.0182
Selenium	3.02
Zinc	1.72

Table 2

Mean concentrations of eight heavy metals for each area sampled compared with Florida's minimum and maximum baseline data in units of mg/Kg (ppm)

Element	Mean for site A	Mean for site B	Mean for site C	Florida' s Baseline Range
As	3.633	3.068	4.833	0.02-7.01
Cd	0.245	0.062	0.020	0-0.33
Cr	13.716	6.731	5.176	0.89-80.7
Cu	17.450	9.620	4.616	0.22-21.9
Pb	4.371	2.176	0.563	0.69-42.0
Hg	0.040	0.011	0.006	0.00075-0.0396
Se	0.000	0.000	0.000	0.01-1.11
Zn	31.050	13.881	7.813	0.89-29.6

* Selenium was not detected (ND) in any of our sediment samples.

Table 3

Heavy Metal Concentrations in Sediments from Peninsula La Esperanza for Zone A.

Point Name- Zone A	Latitude	Longitude	Date Collected	# of sample	As	Cd	Cr	Cu	Pb	Hg	Zn
A1	18° 26.996	66 ° 08.214	4/14/2013	27	4	0	9.7	12.2	3	0.02	20
A2	18° 26.977	66 ° 08.194	4/14/2013	28	4	0	18.6	19.4	7	0.042	47
A3	18° 26.926	66 ° 08.142	4/14/2013	29	7	0	23.8	16.1	2	0.018	20.3
A4	18° 26.917	66 ° 08.132	4/14/2013	30	4	0	16	39.6	7	0.055	53.1
A5	18° 26.904	66 ° 08.131	4/14/2013	31	4	0	13.9	13.6	5	0.059	29.1
*A1C	18° 26.941	66° 08.154	2012	-	1.37	0.457	6.53	13.8	4.25	0.0568	24.1
*A2C	18° 26.980	66° 08.203	2012	-	2.03	0.728	11.8	11.3	3.09	0.0282	30.1
*A3C	18° 27.203	66° 08.324	2012	-	2.66	0.773	9.4	13.6	3.63	0.0382	24.7

* Concentrations were measured in mg/Kg (ppm).
As (Arsenic), Cd (Cadmium), Cr (Chromium), Cu (Copper), Pb (Lead), Mercury (Hg), Zn (Zinc).
Selenium was not detected (ND) in the sediment samples.
n= 8 samples (5 taken for this project and 3 were secondary data from Mejias, Musa and Otero (2012))

Table 4

Heavy Metal Concentrations in Sediments from Peninsula La Esperanza for Zone B.

Point Name-Zone B	Latitude	Longitude	Date Collected	# of sample	As	Cd	Cr	Cu	Pb	Hg	Zn
B1	18° 27.267	66 ° 08.006	4/7/2013	22	3	0	6.1	5.5	1	0.016	9.4
B2	18° 27.243	66° 07.999	4/7/2013	23	3	0	5.7	5	1	0	8.2
B3	18° 27.272	66° 08.064	4/7/2013	24	4	0	4.3	10.8	1	0	9.3
B4	18° 27.447	66° 08.307	4/7/2013	25	2	0	7.3	8.6	3	0	19.6
B5	18° 27.276	66° 08.345	4/7/2013	26	6	0	14.9	28.5	4	0.02	29.4
*B1C	18° 27.400	66° 08.201	2012	-	1.82	0	4.05	4.31	1.48	0	8.35
*B2C	18° 27.284	66° 08.119	2012	-	2.42	0	3.82	4.28	1.51	0.0216	8
*B3C	18° 27.270	66° 08.032	2012	-	2.3	0.498	7.68	9.97	4.42	0.0297	18.8

* Concentrations were measured in mg/Kg (ppm).
As (Arsenic), Cd (Cadmium), Cr (Chromium), Cu (Copper), Pb (Lead), Mercury (Hg), Zn (Zinc).
Selenium was not detected (ND) in the sediment samples.
n= 8 samples (5 taken for this project and 3 were secondary data from Mejias, Musa and Otero (2012)

Table 5

Heavy Metal Concentrations in Sediments from Peninsula La Esperanza for Zone C.

Point Name - Zone C	Latitude	Longitude	Date Collected	# of sample	As	Cd	Cr	Cu	Pb	Hg	Zn
C1	18° 27.143	66° 07.835	10/3/2012	1	6.24	0	6.6	5.7	0	0	8.2
C2	18° 27.144	66° 07.837	10/3/2012	2	10	0	9	7.2	0	0	11.5
C3	18° 27.142	66° 07.836	10/3/2012	3	3.83	0	2.8	2.5	0	0	2.5
C4	18° 27.137	66° 07.835	10/3/2012	4	10	0	8	6.4	0	0	9.5
C5	18° 27.124	66° 07.840	10/3/2012	5	6	0	5.7	4.2	0	0	8.1
C6	18° 27.151	66° 07.844	10/3/2012	6	5	0	5	3.6	0	0	7.9
C7	18° 27.141	66° 07.840	10/3/2012	7	6	0	5	3.8	0	0	7
C8	18° 27.128	66° 07.842	10/3/2012	8	6.47	0	5	4	0	0	7.5
C9	18° 27.099	66° 07.827	10/3/2012	9	5	0	4.9	3.4	0	0	6.2
C10	18° 27.094	66° 07.836	10/3/2012	10	5	0	4.9	3.4	0	0	6.2
C11	18° 27.082	66° 07.789	10/3/2012	11	3	0	2.5	1.9	0	0	2.3
C12	18° 27.068	66° 07.787	10/3/2012	12	3.07	0	3.8	3.3	0	0	5.1
C13	18° 27.053	66° 07.786	10/3/2012	13	4	0	4.1	3.3	0	0	5.4
C14	18° 27.036	66° 07.808	10/3/2012	14	4	0	4.3	2.9	0	0	4.5
C15	18° 27.056	66° 07.785	10/3/2012	15	6	0	6	6.3	0	0	7.4
C16	18° 27.070	66° 07.763	10/3/2012	16	3	0	2.3	1.9	0	0	1.8
C17	18° 26.946	66° 07.934	4/5/2013	17	4	0	4.5	3.8	1	0	8.2
C18	18° 26.956	66° 07.927	4/5/2013	18	4	0	4.2	3.7	1	0	7.7
C19	18° 26.969	66° 07.912	4/5/2013	19	4	0	4.9	3.6	1	0	8.2
C20	18° 26.980	66° 07.895	4/5/2013	20	4	0	9.5	11.8	3	0.043	24.2
C21	18° 26.981	66° 07.873	4/5/2013	21	2	0	5.8	6.9	2	0.03	12.7
*C1C	18° 27.231	66° 08.004	2012	-	4.44	0	4.3	3.81	1.45	0.0247	12.2
*C2C	18° 27.012	66° 07.851	2012	-	3.22	0.486	5.63	7.48	1.99	0.0269	13.2
*C3C	18° 27.011	66° 07.882	2012	-	3.71	0	5.49	5.89	2.08	0.0268	14.8

* Concentrations were measured in mg/Kg (ppm).
As (Arsenic), Cd (Cadmium), Cr (Chromium), Cu (Copper), Pb (Lead), Mercury (Hg), Zn (Zinc).
Selenium was not detected (ND) in the sediment samples.
n= 24 samples (21 taken for this project and 3 were secondary data from Mejias, Musa and Otero (2012))

Table 6

Heavy Metal Concentrations in Leaves from Peninsula La Esperanza for Zone A.

# of sample	Type of Mangrove (B,W,R)	Type of leave (S/N)	As	Cd	Cr	Cu	Pb	Hg	Zn
A1-A4	RED	NEW	0.862	0.431	0.862	1.7	0.431	0.0182	3.3
A1-A4	RED	SEN	0.862	0.431	0.862	0.862	0.431	0.0182	3.1
A1-A4	WHITE	NEW	0.862	0.431	0.862	0.862	0.431	0.0182	9.2
A1-A4	WHITE	SEN	0.862	0.431	0.862	0.862	0.431	0.0182	6.3
A1-A4	BLCK	NEW	0.862	0.431	0.862	2.5	0.431	0.0182	17.6
A1-A4	BLACK	SEN	0.862	0.431	0.862	2.1	0.431	0.02	8.7
A1-A4	RED	NEW	<0.758	<0.379	<0.758	0.869	<0.379	<0.0150	1.83
A1-A4	RED	SEN	<0.833	<0.417	<0.833	<0.833	<0.417	<0.0200	2.19
A1-A4	WHITE	NEW	<0.769	<0.385	<0.769	0.97	<0.385	<0.0146	3.72
A1-A4	WHITE	SEN	<1.00	<0.500	<1.00	<1.00	<0.500	<0.0188	<2.00
A1-A4	BLCK	NEW	<0.909	<0.455	<.909	1.98	<0.455	0.0166	11.7
A1-A4	BLCK	SEN	<0.909	<0.455	<0.909	4.93	0.641	0.0466	9.17
A5-A8	RED	NEW	0.862	0.431	0.862	1	0.431	0.0182	3.2
A5-A8	RED	SEN	0.862	0.431	0.862	1.3	0.431	0.0182	4.8
A5-A8	WHITE	NEW	0.862	0.431	0.862	0.862	0.431	0.0182	4.1
A5-A8	WHITE	SEN	0.862	0.431	0.862	0.862	0.431	0.0182	7.7
A5-A8	BLACK	NEW	0.862	0.431	0.862	2.5	0.431	0.0182	7.6
A5-A8	BLACK	SEN	0.862	0.431	0.862	2.5	0.431	0.0182	7.6

*Please refer to Figure
Concentrations are in mg/Kg (ppm)/ Se was not detected (ND) in leaves samples

Table 7

Heavy Metal Concentrations in Leaves from Peninsula La Esperanza for Zone B.

# of sample	Type of Mangrove (B,W,R)	Type of leave (S/N)	As	Cd	Cr	Cu	Pb	Hg	Zn
B1-B5	RED	NEW	0.862	0.431	0.862	0.862	0.431	0.0182	2.1
B1-B5	RED	SEN	0.862	0.431	0.862	0.862	0.431	0.0182	1.9
B1-B5	WHITE	NEW	0.862	0.431	0.862	1.6	0.431	0.0182	3.9
B1-B5	WHITE	SEN	0.862	0.431	0.862	0.862	0.431	0.0182	1.72
B1-B5	BLACK	NEW	0.862	0.431	0.862	0.862	0.431	0.0182	4.6
B1-B5	BLACK	SEN	0.862	0.431	0.862	0.862	0.431	0.0182	8.9
B1-B5	RED	NEW	<1.00	<0.500	<1.00	<1.00	<.500	<0.0158	<2.00
B1-B5	RED	SEN	<0.794	<0.397	<0.794	<0.794	<0.397	<0.0150	<1.59
B1-B5	WHITE	NEW	<0.962	<0.481	<0.962	<0.962	<0.481	<0.0150	4.08
B1-B5	WHITE	SEN	<0.667	<0.333	<0.667	<0.667	<0.333	0.0218	9.67
B1-B5	BLACK	NEW	<0.893	<0.446	<0.893	1.5	<0.446	0.0207	4.34
B1-B5	BLACK	SEN	<1.00	<0.500	<1.00	1.78	0.571	0.0342	6.35
B6-B8	RED	NEW	0.862	0.431	0.862	0.862	0.431	0.0182	1.72
B6-B8	RED	SEN	0.862	0.431	0.862	1.2	0.431	0.0182	3.6
B6-B8	WHITE	NEW	0.862	0.431	0.862	1.2	0.431	0.0182	5.7
B6-B8	WHITE	SEN	0.862	0.431	0.862	0.862	0.431	0.024	6
B6-B8	BLACK	NEW	0.862	0.431	0.862	2	0.431	0.0182	19.5
B6-B8	BLACK	SEN	1	0.431	0.862	1	0.431	0.026	10.1

* Concentrations are in mg/Kg (ppm)/ Se was not detected (ND) in leaves samples

Table 8

Heavy Metal Concentrations in Leaves from Peninsula La Esperanza for Zone C.

# of sample	Type of Mangrove (B,W,R)	Type of leave (S/N)	As	Cd	Cr	Cu	Pb	Hg	Zn
C1-C11	RED	NEW	0.862	0.431	0.862	2.3	0.431	0.0182	2
C1-C11	RED	SEN	0.862	0.431	0.862	0.862	0.431	0.0182	1.72
C1-C11	WHITE	NEW	0.862	0.431	0.862	0.862	0.431	0.0182	2.2
C1-C11	WHITE	SEN	0.862	0.431	0.862	0.862	0.431	0.0182	1.72
C1-C11	BLACK	NEW	0.862	0.431	0.862	0.862	0.431	0.0182	8.9
C1-C11	BLACK	SEN	0.862	0.431	0.862	0.862	0.431	0.024	6.4
C12-C18	RED	NEW	0.862	0.431	0.862	1.8	0.431	0.0182	1.72
C12-C18	RED	SEN	0.862	0.431	0.862	0.862	0.431	0.0182	2.6
C12-C18	WHITE	NEW	0.862	0.431	0.862	1.1	1	0.0182	3.4
C12-C18	WHITE	SEN	0.862	0.431	0.862	0.862	0.431	0.0182	8.4
C12-C18	BLACK	NEW	0.862	0.431	0.862	4.8	0.431	0.0182	10.4
C12-C18	BLACK	SEN	1	0.431	0.862	2.1	0.431	0.022	7.8
C12-C18	RED	NEW	<0.943	<0.472	<0.943	<0.943	<0.472	<0.0194	<1.89
C12-C18	RED	SEN	<0.781	<0.391	<0.781	<0.781	<0.391	<0.0200	<1.56
C12-C18	WHITE	NEW	<0.862	<0.431	<0.862	1.19	<0.431	<0.0194	6.17
C12-C18	WHITE	SEN	<0.847	<0.424	<0.847	<0.847	<0.424	<0.0188	3.9
C12-C18	BLACK	NEW	<1.00	<0.500	<1.00	<1.00	<0.500	<0.0143	3.51
C12-C18	BLACK	SEN	<0.980	<0.490	<0.980	<0.980	0.52	0.0244	4.29

Continuation of Table 8

Heavy Metal Concentrations in Leaves from Peninsula La Esperanza for Zone

# of sample	Type of Mangrove (B,W,R)	Type of leave (S/N)	As	Cd	Cr	Cu	Pb	Hg	Zn
C17-C24	RED	NEW	0.862	0.431	0.862	0.862	0.431	0.0182	1.72
C17-C24	RED	SEN	0.862	0.431	0.862	0.862	0.431	0.0182	2
C17-C24	WHITE	NEW	0.862	0.431	0.862	1.8	0.431	0.0182	3.7
C17-C24	WHITE	SEN	0.862	0.431	0.862	0.862	0.431	0.0182	2.6
C17-C24	BLACK	NEW	0.862	0.431	0.862	1.8	0.431	0.017	7.9
C17-C24	BLACK	SEN	0.862	0.431	0.862	1.1	0.431	0.037	7.1

* Concentrations are in mg/Kg (ppm)/ Se was not detected (ND) in leaves samples

Table 9

Bioconcentration Factors (BCF's) for Green Leaves in Zone A.

Mangrove Species	Green Leaves BCF's					
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Zinc
R. MANGLE	0.2277	1.690	0.0603	0.0681	0.0946	0.4321	0.0894
A.GERMINANS	0.2416	1.793	0.0639	0.1020	0.1004	0.4455	0.3972
L.RACEMOSA	0.2287	1.698	0.0605	0.0514	0.0950	0.4287	0.1827

Table 10

Bioconcentration Factors (BCF's) for Senescent Leaves in Zone A.

Mangrove Species	Senescent Leaves BCF's						
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Zinc
R. MANGLE	0.2346	1.741	0.0621	0.0572	0.0975	0.4741	0.1083
A.GERMINANS	0.2416	1.793	0.0639	0.1820	0.1146	0.7129	0.2734
L.RACEMOSA	0.2499	1.854	0.0661	0.0520	0.1038	0.4640	0.1717

Table 11

Bioconcentration Factors (BCF's) of Green Leaves in Zone B.

Mangrove Species	**Green Leaves BCF's**						
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Zinc
R. MANGLE	0.2960	7.293	0.1348	0.0943	0.2086	1.594	0.1397
A. GERMINANS	0.2843	7.004	0.1295	0.1511	0.2003	1.744	0.6829
L. RACEMOSA	0.2918	7.191	0.1330	0.1303	0.2057	1.570	0.3285

Table 12

Bioconcentration Factors (BCF's) of Senescent Leaves in Zone B.

Mangrove Species	**Senescent Leaves BCF's**						
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Zinc
R. MANGLE	0.2736	6.741	0.1246	0.0989	0.1928	1.570	0.1702
A. GERMINANS	0.3110	7.293	0.1348	0.1261	0.2194	2.394	0.6087
L. RACEMOSA	0.2598	6.398	0.1184	0.0828	0.1830	1.954	0.4175

Table 13

Bioconcentration Factors (BCF's) for Green Leaves in Zone C.

Mangrove Species	**Green Leaves BCF's**					
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Zinc
R. MANGLE	0.1825	21.79	0.1704	0.3198	0.7832	2.932	0.2345
A. GERMINANS	0.1855	27.45	0.1732	0.4583	0.7957	2.682	0.9827
L.RACEMOSA	0.1560	21.28	0.1665	0.2682	1.017	2.932	0.4950

Table 14

Bioconcentration Factors (BCF's) for Senescent Leaves in Zone C.

Mangrove Species	**Senescent Leaves BCF's**						
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Zinc
R. MANGLE	0.1741	20.79	0.1626	0.1823	0.7473	2.956	0.2521
A. GERMINANS	0.2504	22.01	0.1722	0.2730	0.8045	4.256	0.8188
L.RACEMOSA	0.1775	21.19	0.1658	0.1859	0.7619	2.908	0.6048

Table 15

Retranslocation Percents (RT) for the three species of mangroves in Zones C, B and A

RT by Zone	Mangrove Species	As	Cd	Cr	Cu	Pb	Hg	Zn
RT FOR C	R. mangle	4.59053556	4.58923513	4.59053556	42.980525	4.58923513	-0.8108108	-7.5034106
	A. germinans	-35.025098	19.8291367	0.55772448	40.4159773	-1.115449	-58.641064	16.6720938
	L. racemosa	-13.788532	0.40603248	0.4350348	30.674475	25.1199302	0.81081081	-22.171946
RT FOR B								
	R. mangle	7.56240822	7.56240822	7.56240822	-4.845815	7.56240822	1.53256705	-21.821306
	A. germinans	-9.3618647	-4.1284404	-4.0886511	16.5061898	-9.5565749	-37.302977	10.8649789
	L. racemosa	10.9828742	11.0201042	10.9828742	36.4433812	11.0201042	-24.513619	-27.119883
RT FOR A	R. mangle	-3.0217566	-3.0620467	-3.0217566	16.0829364	-3.0620467	-9.7276265	-21.128451
	A. germinans	0	0	0	-78.397604	-14.123007	-60	31.1621622
	L. racemosa	-9.2659446	-9.2221331	-9.2659446	-1.1135857	-9.2221331	-8.2352941	5.99294947

* RT percents were calculated using the formula described in the methodology. Please refer to page 34. (with formulas)

FIGURES

Figure 1. Peninsula La Esperanza Study Site, Cataño, P.R.

Figure 2. Sampling zones (sites) A, B, and C at Peninsula La Esperanza.

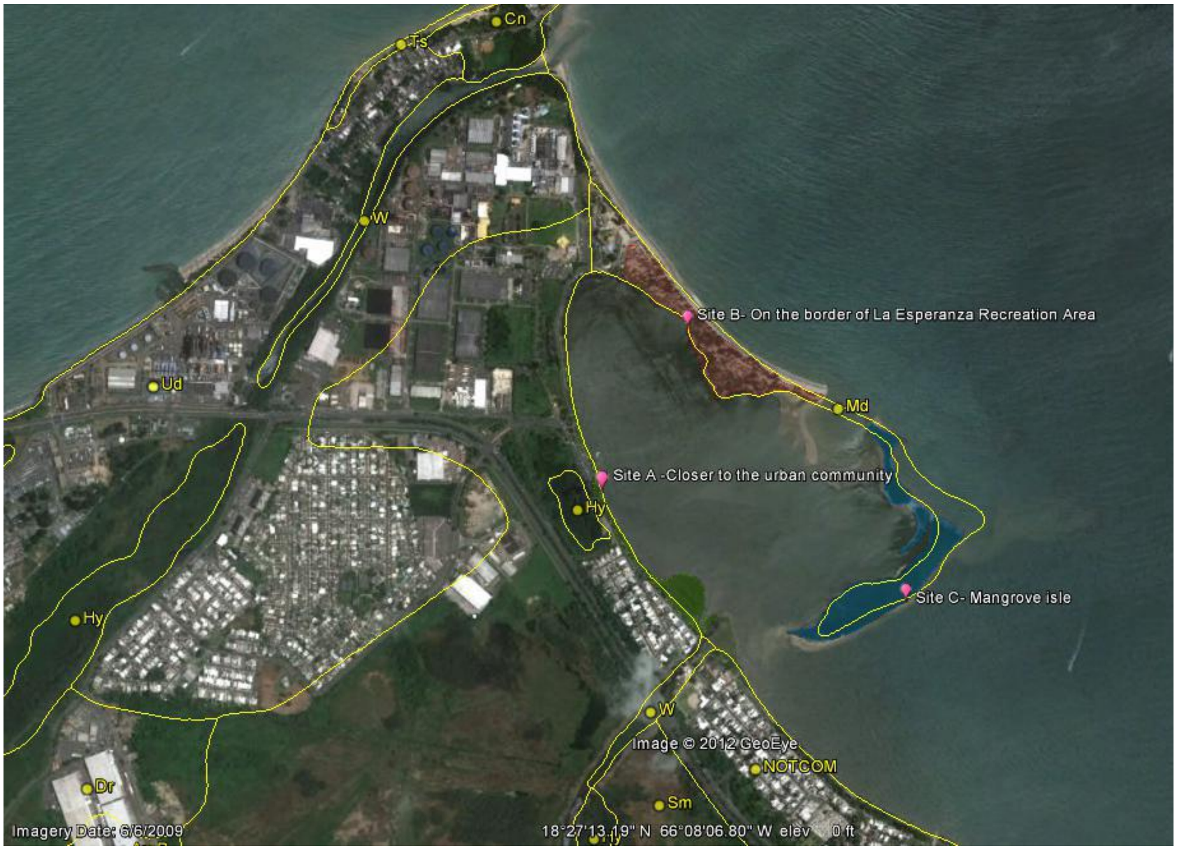


Figure 3. Soil type distribution from Peninsula La Esperanza, Cataño. Adapted from USDA/NRCS

 1995

 2004

 2012

Figure 4: Changes in ocean influx to Peninsula La Esperanza.

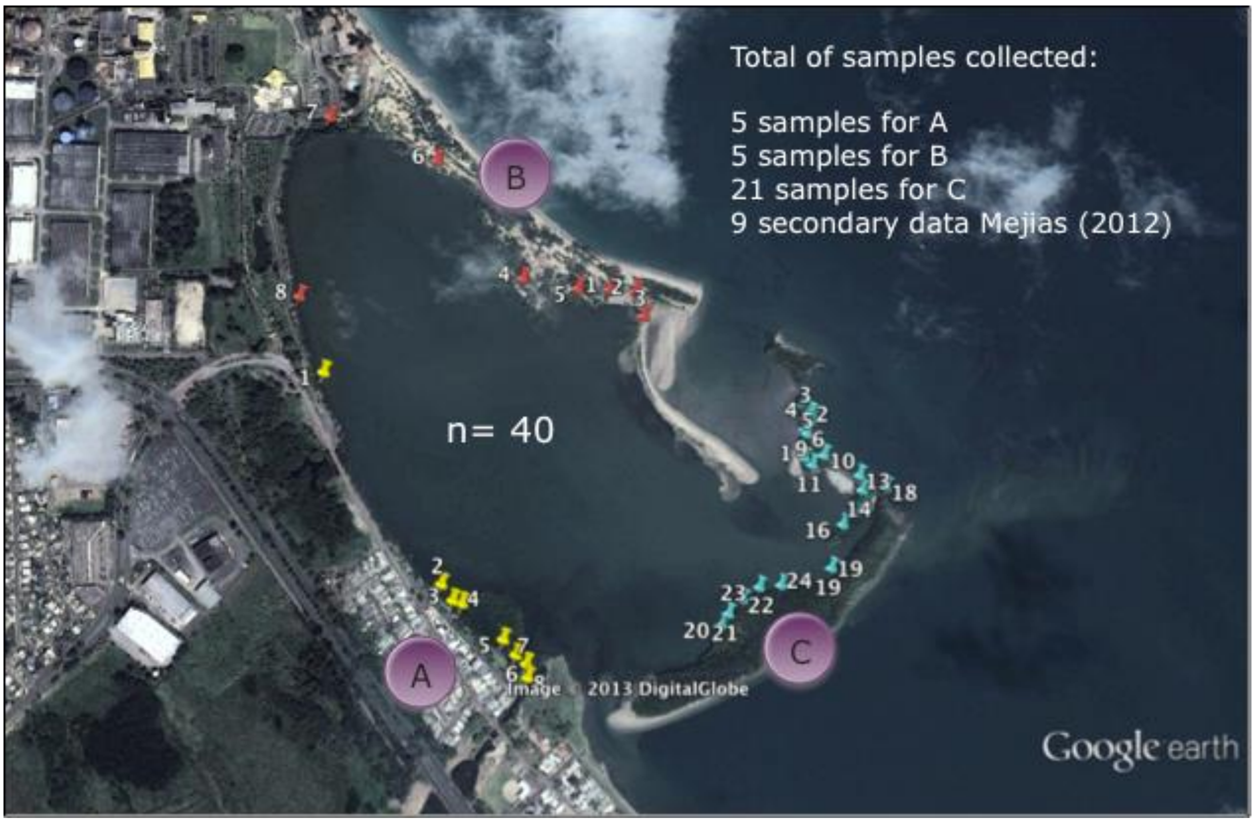


Figure 5. Sediment samples taken in Zones A, B and C.

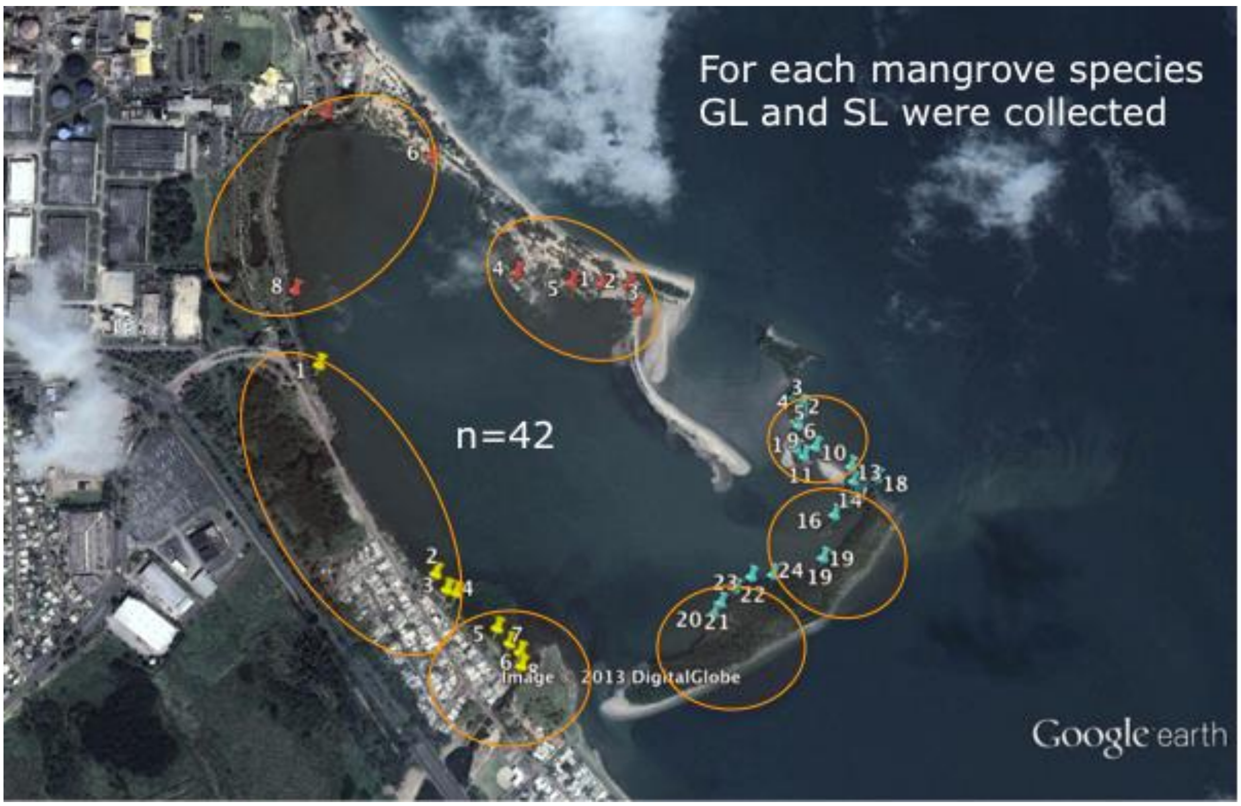


Figure 6: Mangrove leaves sampling areas.

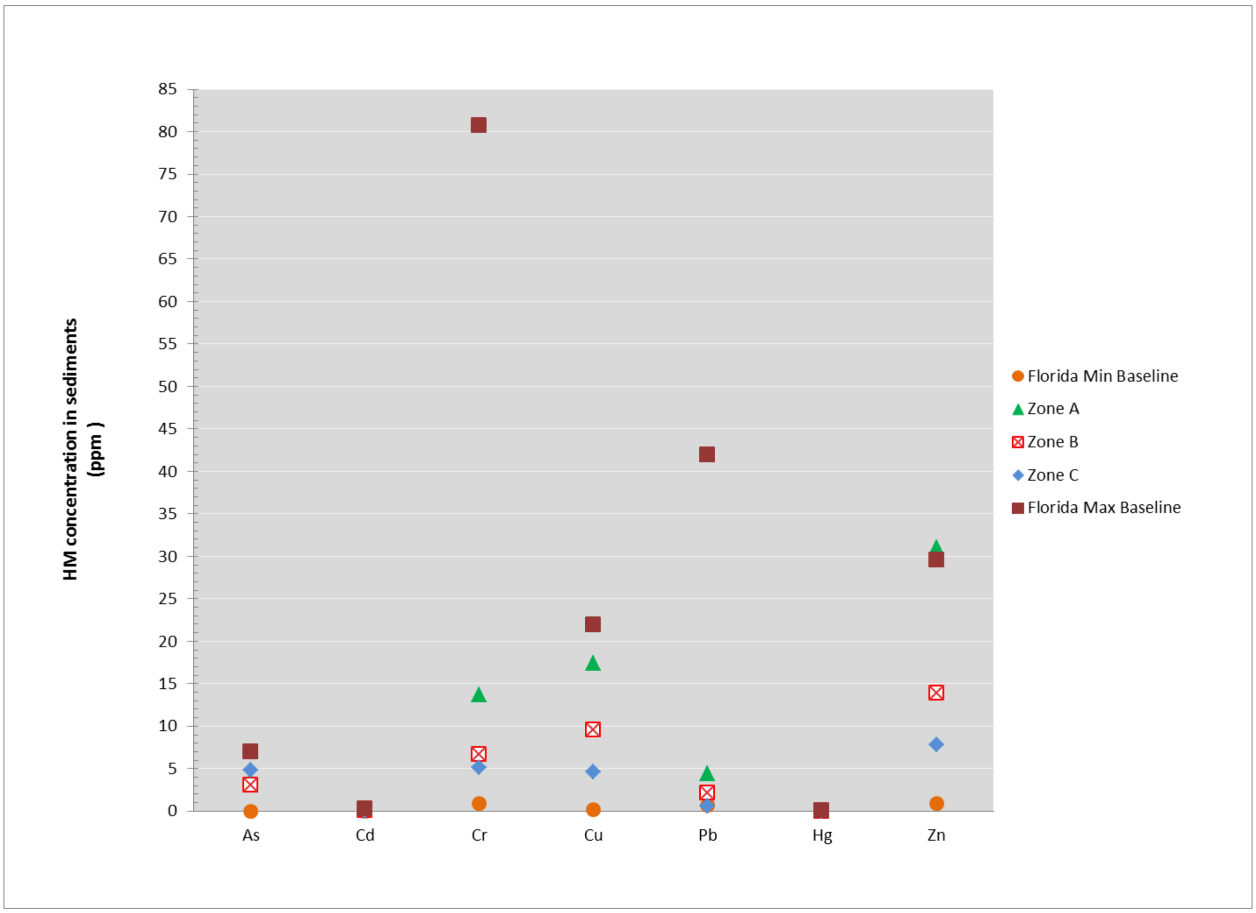
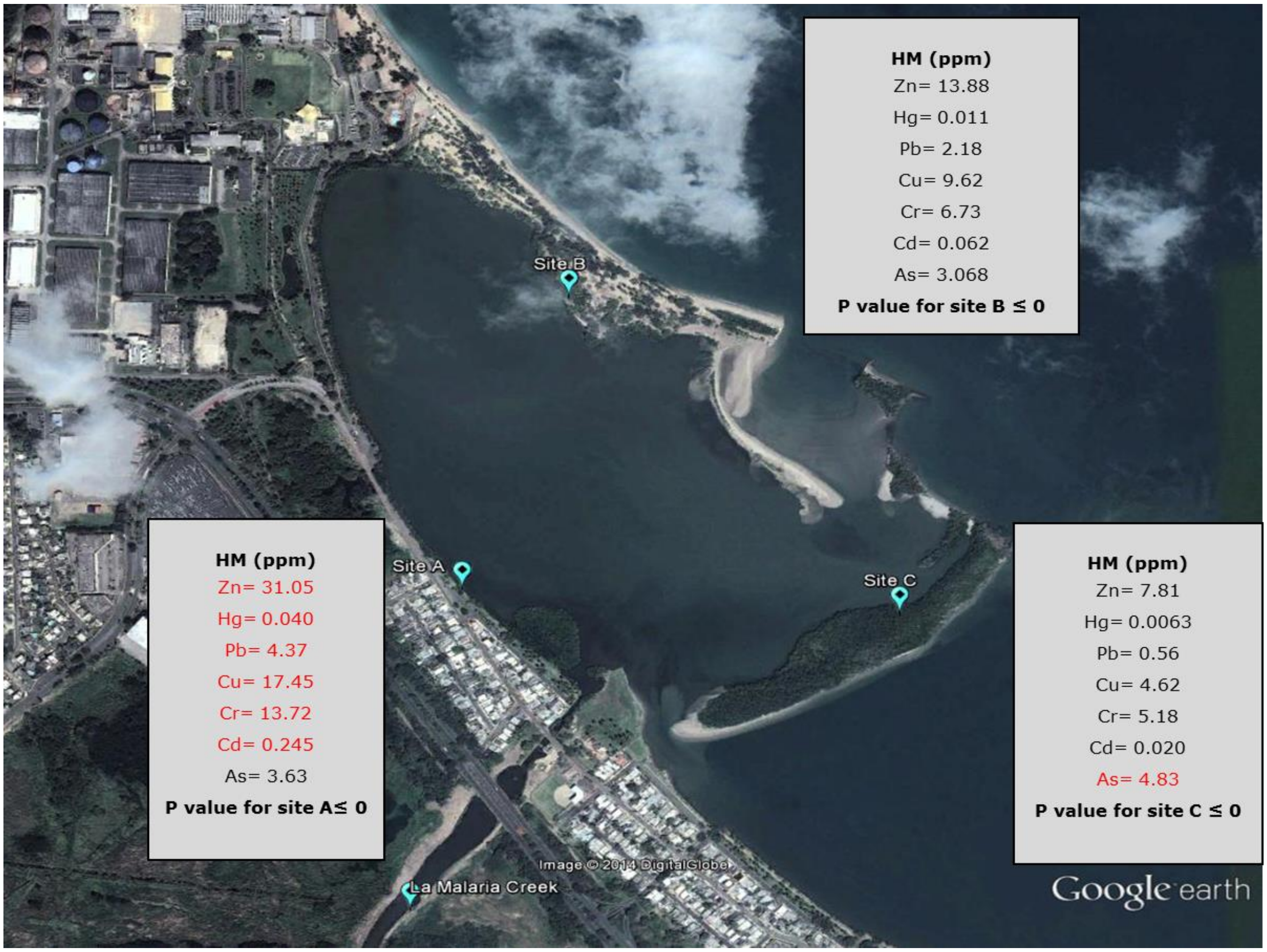
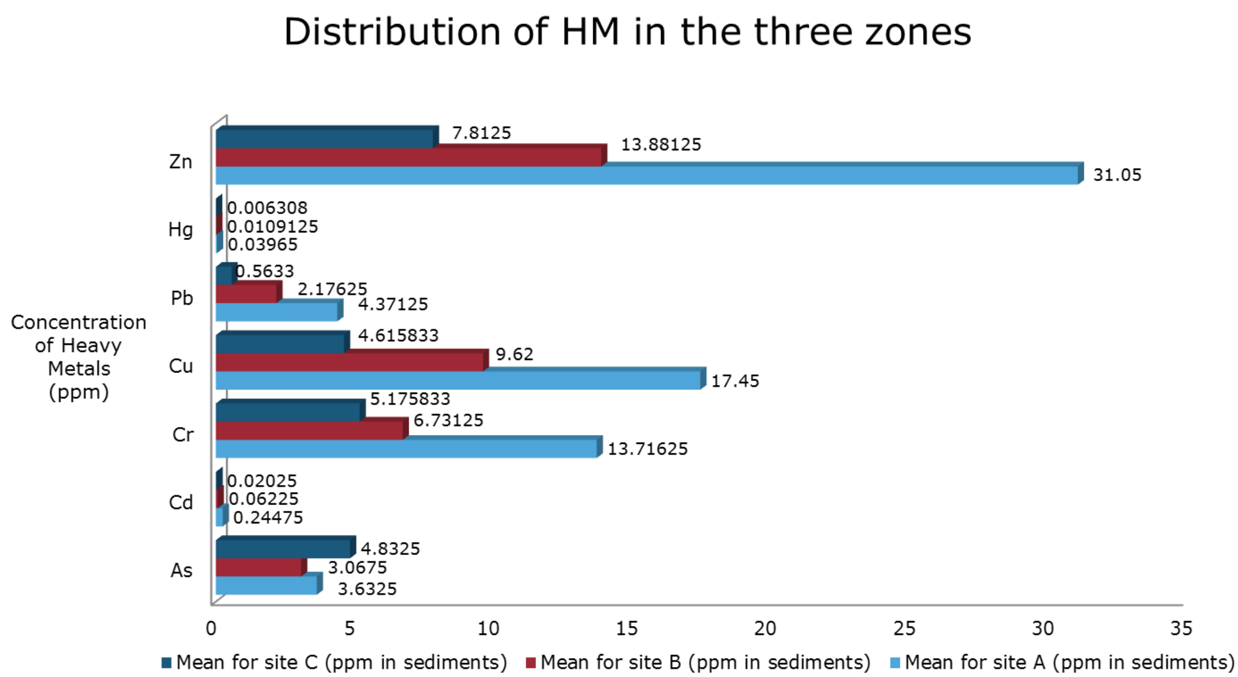


Figure 7: Comparison of Heavy Metal concentrations found in Peninsula La Esperanza and the Baseline Concentrations for Florida's soils.



* P values when comparing the distribution of 7 metals within each of the zones or sampling sites. Higher values shown in red.

Figure 8: Mean Distribution of Heavy Metal Concentrations per Area.



** Anova using Minitab 14: As= p value 0.045, Cd =p value 0.021, All others p value= 0 (When comparing each concentration of each heavy metal among the three zones studied)

Figure 9: Distribution of Heavy Metals in sediments in the three zones sampled at Peninsula La Esperanza.

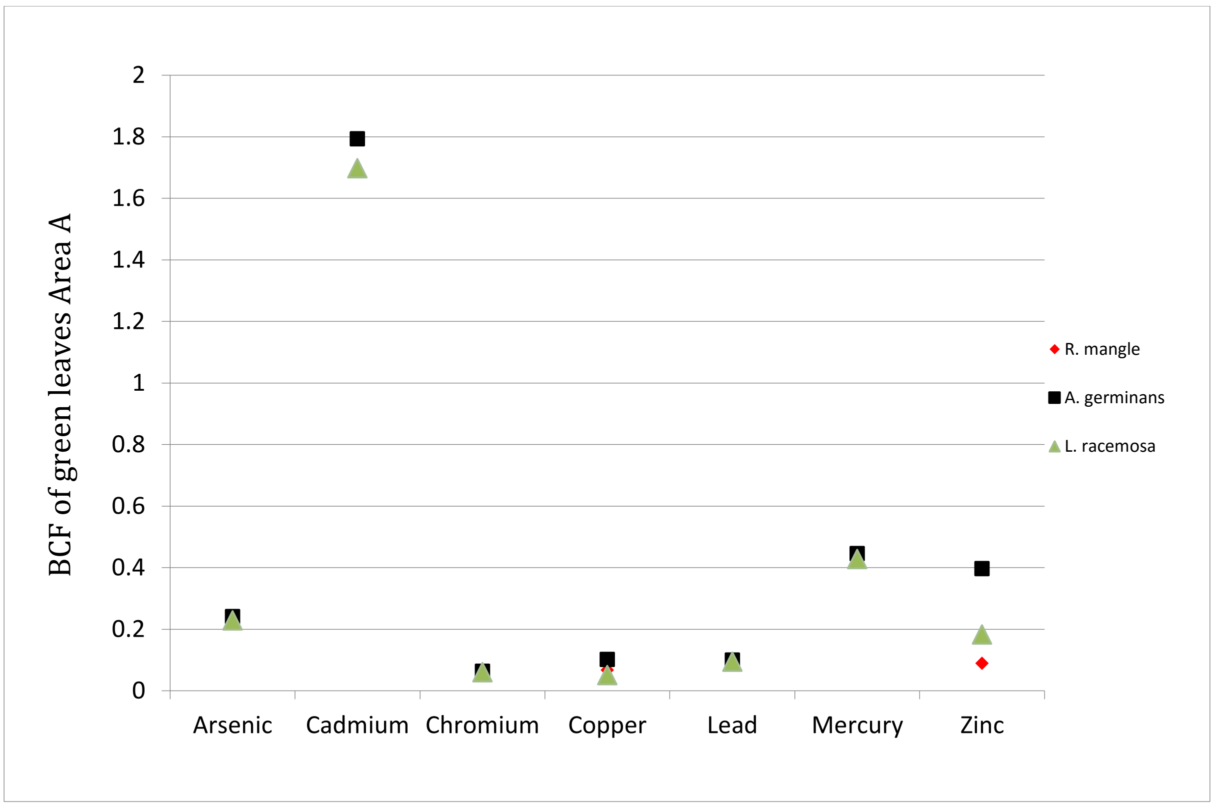


Figure 10: BCF's (Bioconcentration Factors) for Green leaves for *Rhyzhophora mangle* (Red mangrove), *Laguncularia racemosa* (White mangrove) and *Avicennia germinans* (Black mangrove) in the Area A.

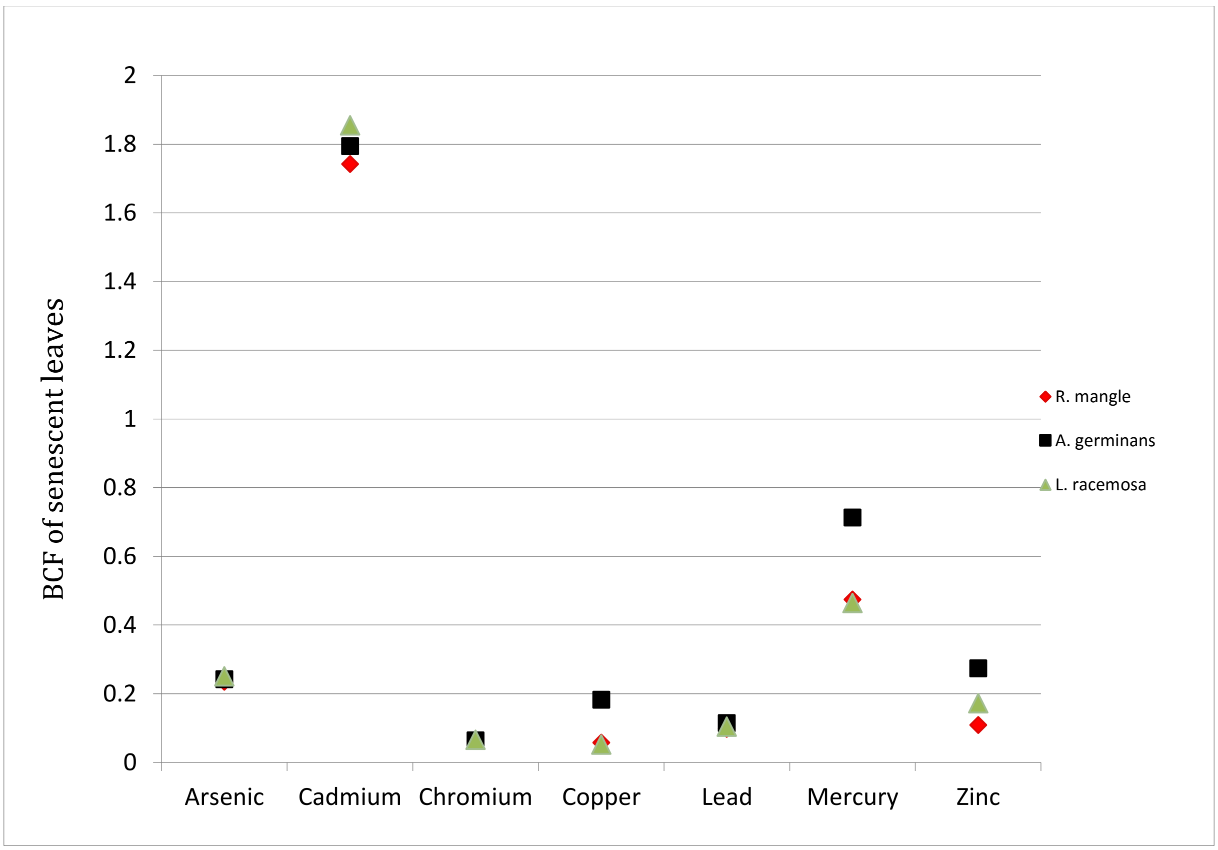


Figure 11: BCF's (Bioconcentration Factors) for Senescent leaves for *Rhyzhophora mangle* (Red mangrove), *Laguncularia racemosa* (White mangrove) and *Avicennia germinans* (Black mangrove) in the Area A.

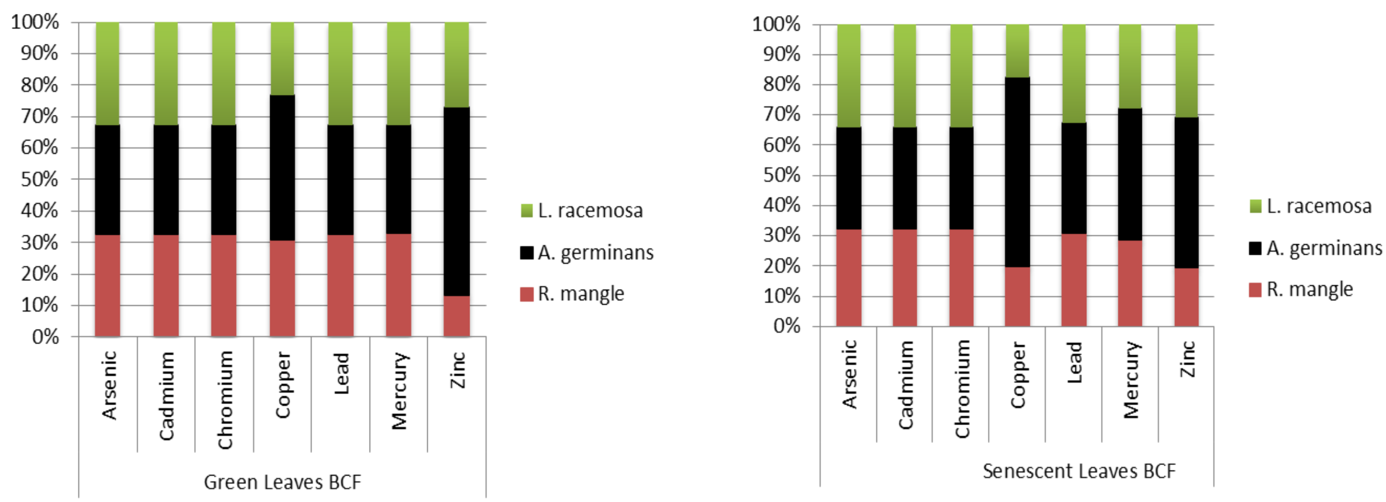


Figure 12: BCF's (Bioconcentration Factors) in Percents for Green and Senescent leaves for *Rhyzhophora mangle* (Red mangrove), *Laguncularia racemosa* (White mangrove) and *Avicennia germinans* (Black mangrove) in the Area A.

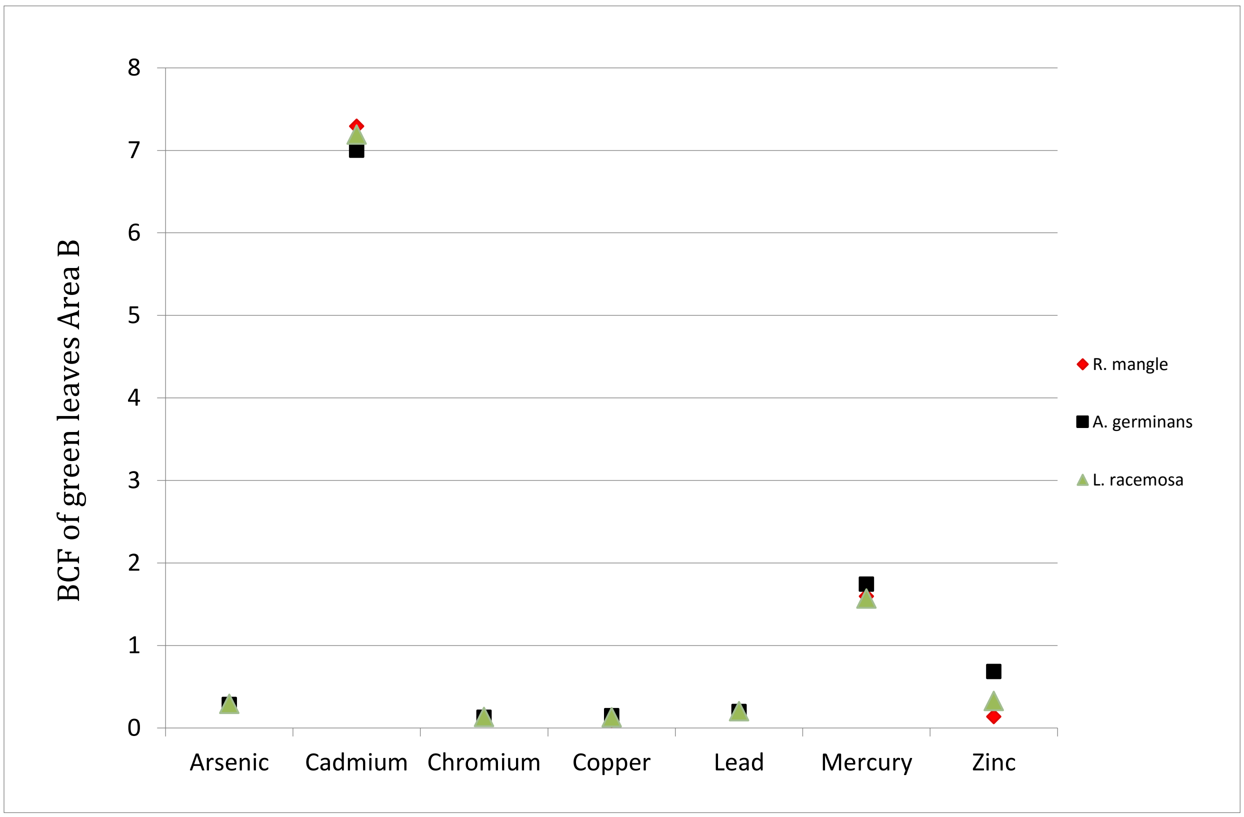


Figure 13: BCF's (Bioconcentration Factors) for Green Leaves for *Rhyzhophora mangle* (Red mangrove), *Laguncularia racemosa* (White mangrove) and *Avicennia germinans* (Black mangrove) in the Area B.

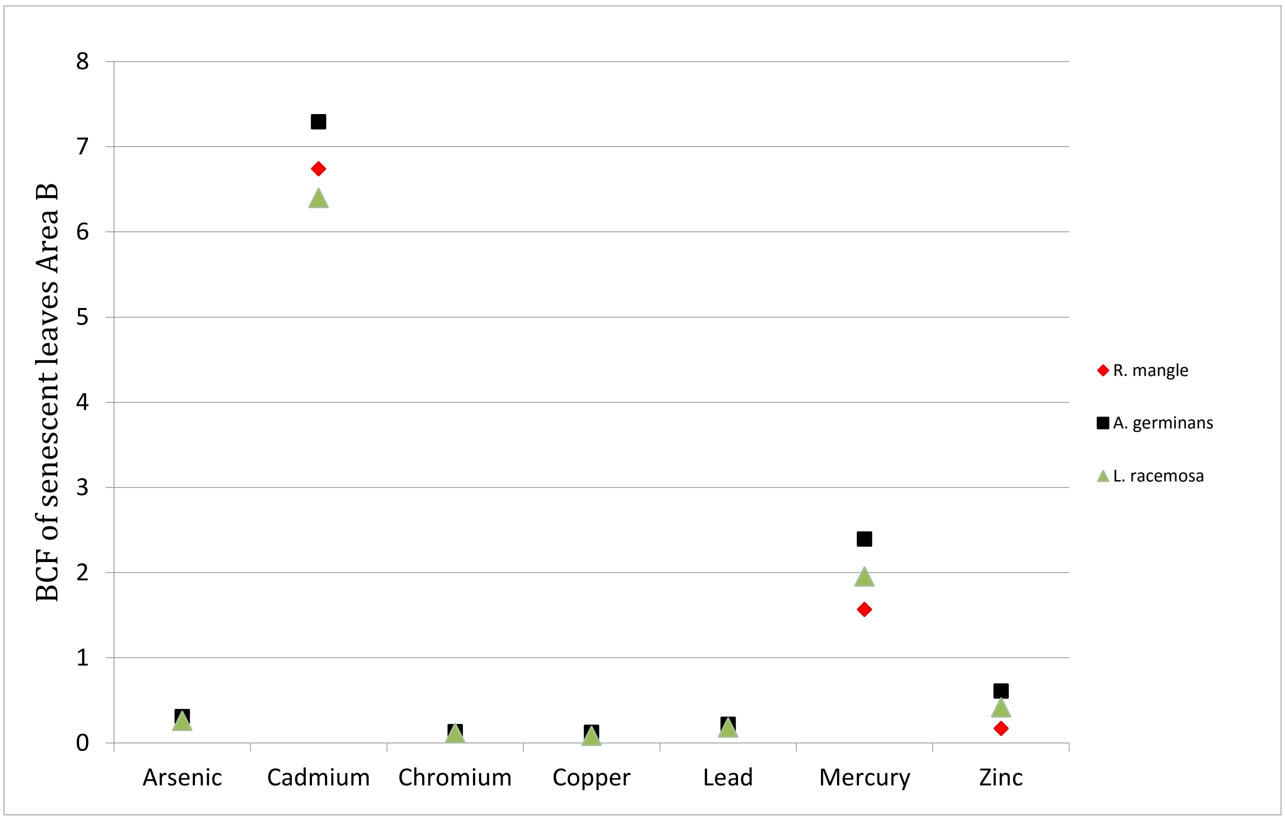


Figure 14: BCF's (Bioconcentration Factors) for Senescent Leaves for *Rhyzhophora mangle* (Red mangrove), *Laguncularia racemosa* (White mangrove) and *Avicennia germinans* (Black mangrove) in the Area B.

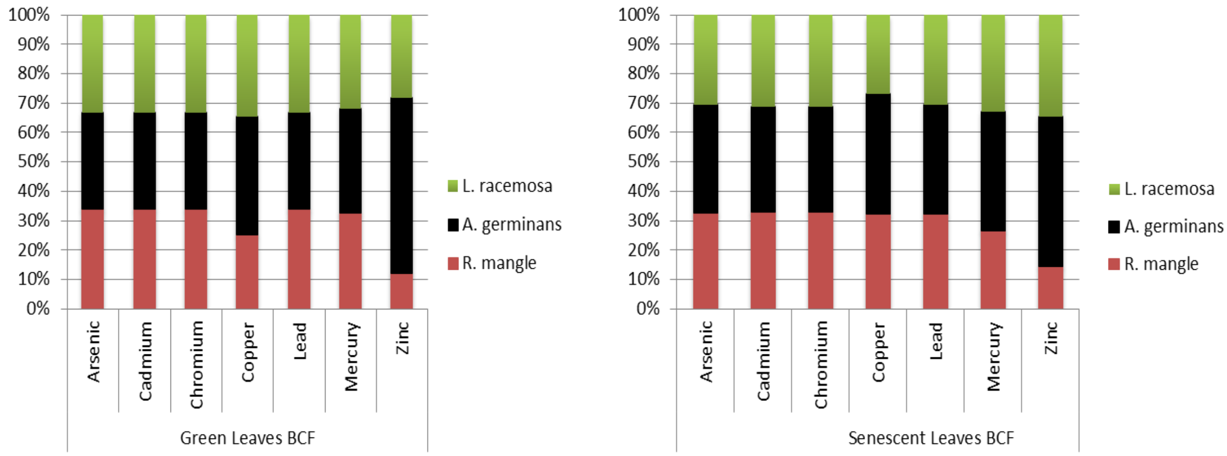


Figure 15: BCF's (Bioconcentration Factors) in Percents for Green and Senescent leaves for *Rhyzhophora mangle* (Red mangrove), Laguncularia *racemosa* (White mangrove) and *Avicennia germinans* (Black mangrove) in the Area B.

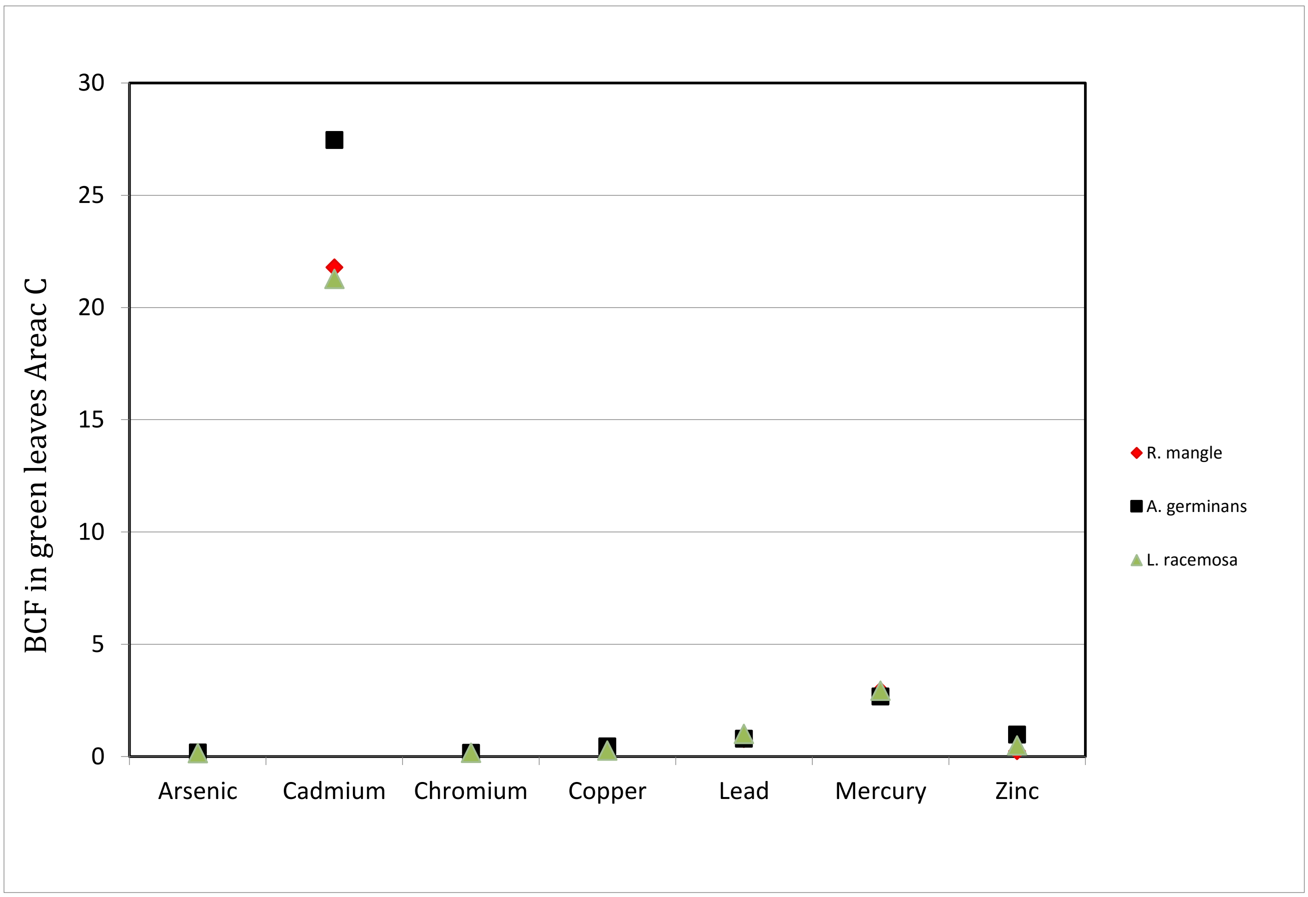


Figure 16: BCF's (Bioconcentration Factors) for Green Leaves for *Rhyzhophora mangle* (Red mangrove), *Laguncularia racemosa* (White mangrove) and *Avicennia germinans* (Black mangrove) in the Area C.

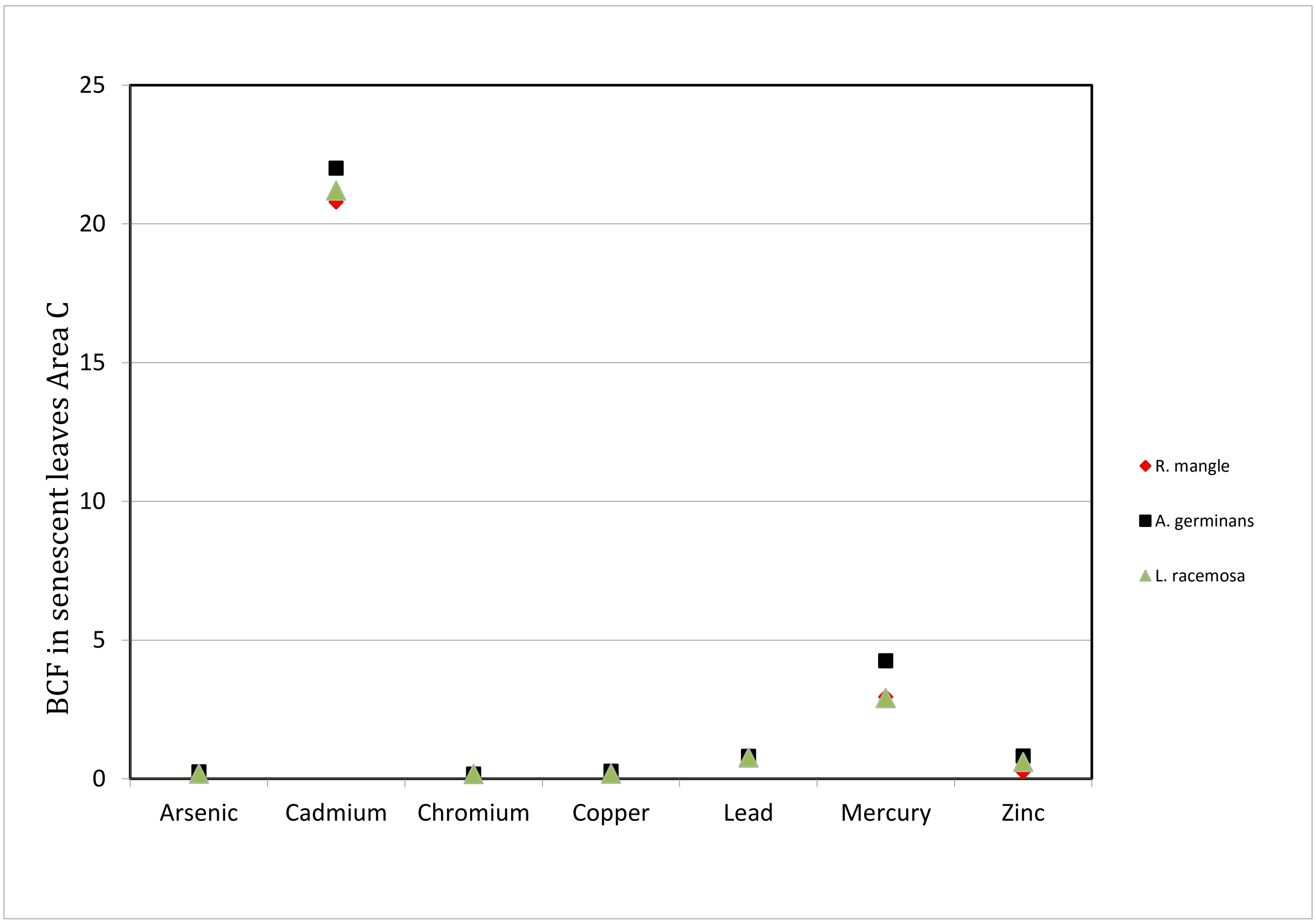


Figure 17: BCF's (Bioconcentration Factors) for Senescent Leaves for *Rhyzhophora mangle* (Red mangrove), *Laguncularia racemosa* (White mangrove) and *Avicennia germinans* (Black mangrove) in the Area C.

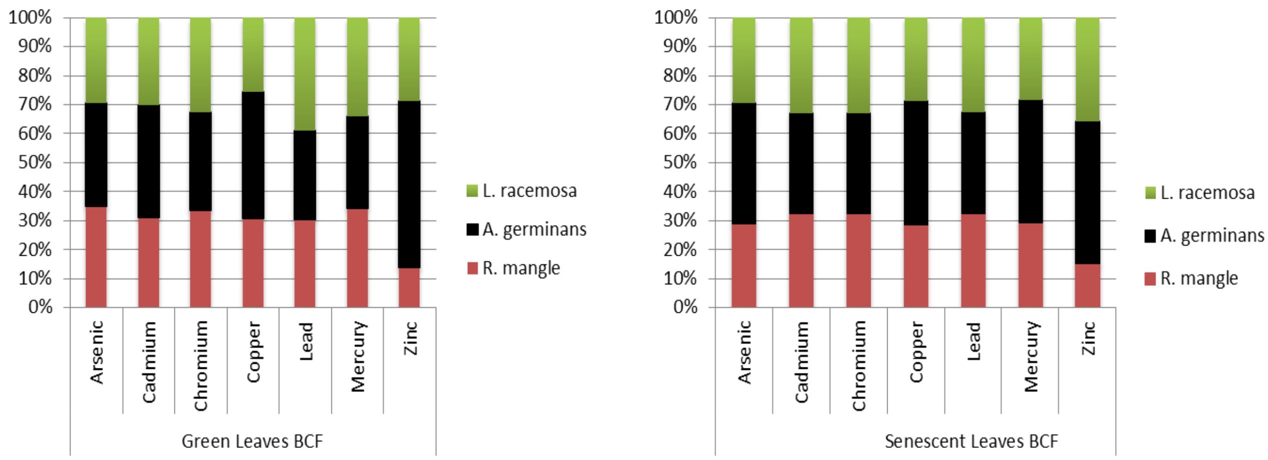


Figure 18: BCF's (Bioconcentration Factors) in Percents for Green and Senescent leaves for *Rhyzhophora mangle* (Red mangrove), Laguncularia *racemosa* (White mangrove) and *Avicennia germinans* (Black mangrove) in the Area C.

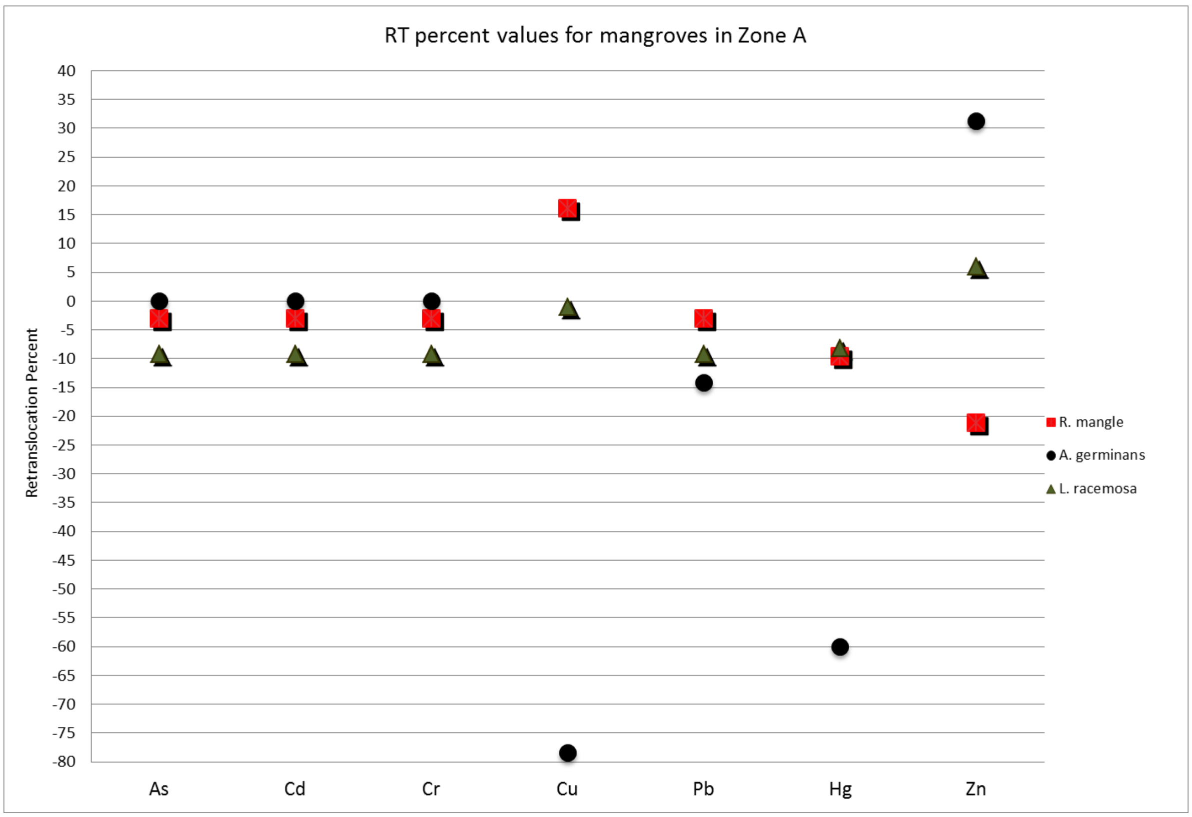


Figure 19: Retranslocation percent of each mangrove species for Area A.

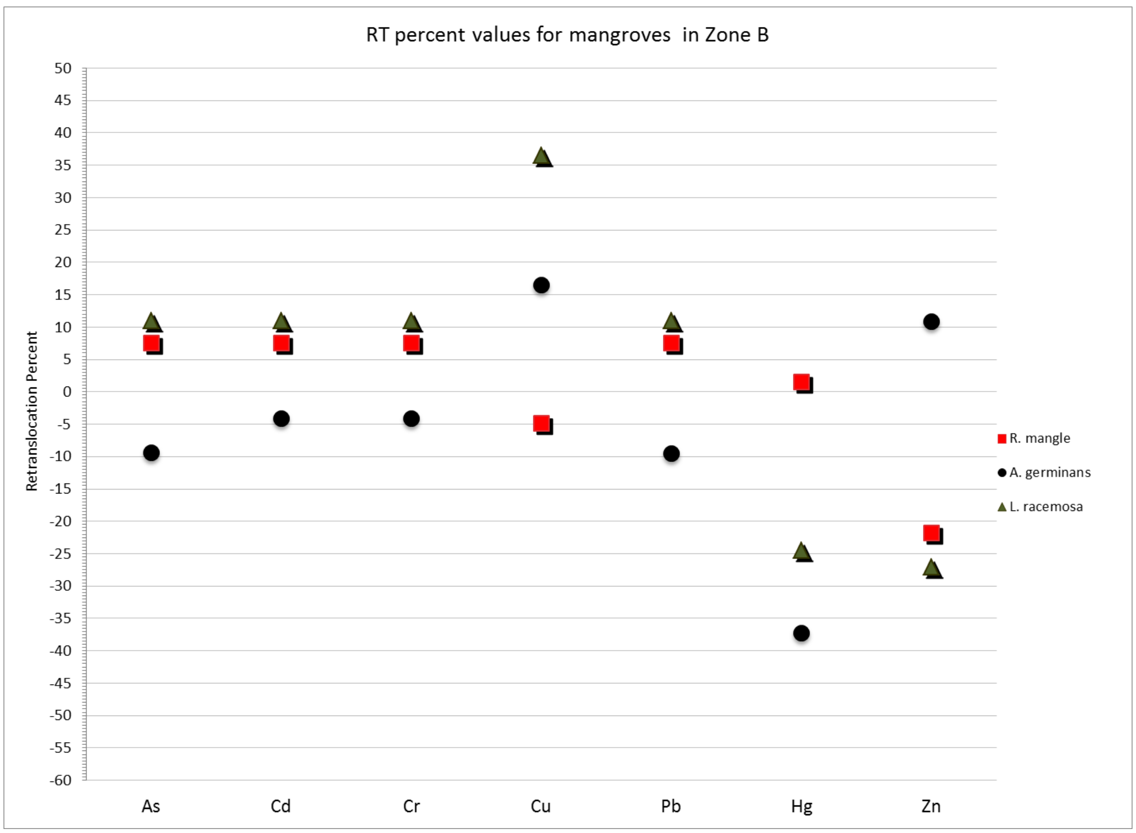


Figure 20: Retranslocation percent of each mangrove species for Area B.

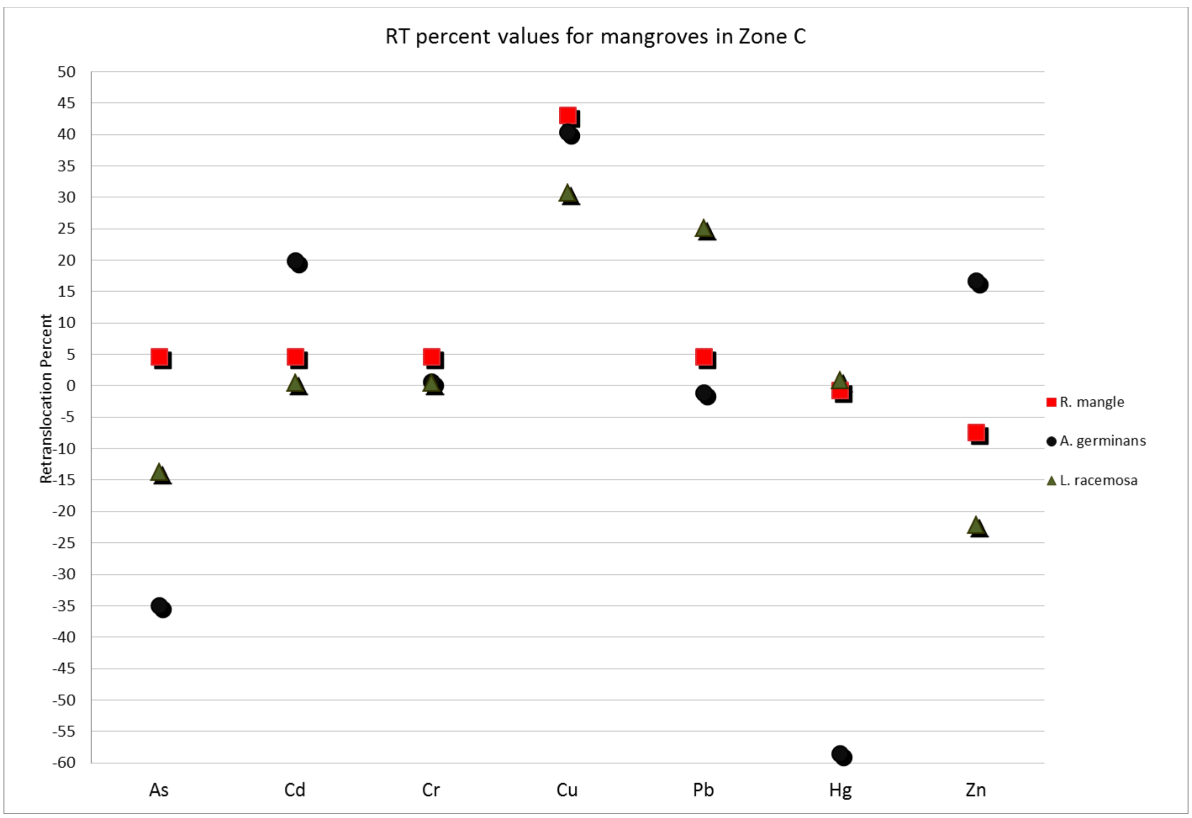


Figure 21: Retranslocation percent of each mangrove species for Area C.

APPENDIX 1

LABORATORY ANALYSIS FOR SEDIMENTS AND LEAVES

Sanco Laboratories, Inc.
Quality and Reliability Since 1975

January 2, 2012

Dr. Juan C. Musa
Universidad Metropolitana, UMET
P.O. Box 21150
San Juan, PR 00928-1150

LABORATORY REPORT

Project ID	: 121116I001	**Customer ID**	: 581
Project Description	: Península La Esperanza, Cataño, PR		
Sample(s) Submitted By	: Universidad Metropolitana, UMET	**Date Received**	: 11/15/2012
Sampled By	: Client	**Date Collected**	: 10/3/2012
Sample(s) Log Number	: 121116I001 to 121116I016		

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
121116I001	**#1 Area C**	Arsenic	S	EPA 6010	mg/L	---	6.240	11/28/2012	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	6.6	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	5.7	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	8.2	11/28/2012	pa
121116I002	**#2 Islote**	Arsenic	S	EPA 6010	mg/kg	---	10	11/28/2012	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	9.0	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	7.2	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	11.5	11/28/2012	pa

P.O. Box 10359, San Juan, P.R., 00922-0359 Tel. (787) 781-2094 / 782-2053 Fax. (787) 792-5821

Sanco Laboratories, Inc.
Sample(s) Log Number : 1211161001 to 1211161016

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
1211161003	#3 Blk + Wht Mangle	Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	2.8	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	2.5	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	2.5	11/28/2012	pa
		Arsenic	S	EPA 7010	mg/kg	---	3.830	11/28/2012	pa
1211161004	#4 Blk + Wht Isle	Arsenic	S	EPA 6010	mg/kg	---	10	11/28/2012	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	8.0	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	6.4	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	9.5	11/28/2012	pa
1211161005	#5 Blk Pine	Arsenic	S	EPA 6010	mg/kg	---	6	11/28/2012	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	5.7	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	4.2	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	12/17/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	8.1	11/28/2012	pa
1211161006	#6 Area C	Arsenic	S	EPA 6010	mg/kg	---	5	11/28/2012	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	5.0	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	3.6	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	7.9	11/28/2012	pa

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Sample(s) Log Number : 121116I001 to 121116I016

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
121116I007	#7 Interest + Soil Casua	Arsenic	S	EPA 6010	mg/kg	---	6	11/28/2012	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	5.0	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	3.8	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	7.0	11/28/2012	pa
121116I008	#8 Red Mangrove	Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	5.0	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	4.0	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	7.5	11/28/2012	pa
		Arsenic	S	EPA 7010	mg/kg	---	6.470	11/28/2012	pa
121116I009	#9 Area C	Arsenic	S	EPA 6010	mg/kg	---	5	11/28/2012	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	4.9	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	3.4	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	6.2	11/28/2012	pa

Sanco Laboratories, Inc.
Sample(s) Log Number : 1211161001 to 1211161016

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
1211161010	#10 Area C	Arsenic	S	EPA 6010	mg/kg	---	5	11/28/2012	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	4.9	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	3.4	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	6.2	11/28/2012	pa
1211161011	#11 Area C	Arsenic	S	EPA 6010	mg/kg	---	3	11/28/2012	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	2.5	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	1.9	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	2.3	11/28/2012	pa
1211161012	#12 Area C	Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	3.8	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	3.3	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	5.1	11/28/2012	pa
		Arsenic	S	EPA 7010	mg/kg	---	3.070	11/28/2012	pa
1211161013	#13 Area C	Arsenic	S	EPA 6010	mg/kg	---	4	11/28/2012	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	4.1	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	3.3	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	5.4	11/28/2012	pa

Sanco Laboratories, Inc.
Sample(s) Log Number : 121116I001 to 121116I016

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
121116I014	#14 Area C	Arsenic	S	EPA 6010	mg/kg	---	4	11/28/2012	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	4.3	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	2.9	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	4.5	11/28/2012	pa
121116I015	#15 Area C	Arsenic	S	EPA 6010	mg/kg	---	6	11/28/2012	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	6.0	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	6.3	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	7.4	11/28/2012	pa
121116I016	#16 Area C	Arsenic	S	EPA 6010	mg/kg	---	3	11/28/2012	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Chromium	S	EPA 6010	mg/kg	---	2.3	11/28/2012	pa
		Copper	S	EPA 6010	mg/kg	---	1.9	11/28/2012	pa
		Lead	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Mercury	S	EPA 7471	mg/kg	---	ND	11/28/2012	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	11/28/2012	pa
		Zinc	S	EPA 6010	mg/kg	---	1.8	11/28/2012	pa

S - Solid
ND - Not Detected

Revised by:
Lic. Enid Ortiz
Q.A. Manager

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May 29, 2013

Juan C. Musa / Marixa Maldonado
Universidad Metropolitana, UMET
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San Juan, PR 00928-1150

LABORATORY REPORT

Project ID : 130426K001
Project Description : Forest Service Study
Customer ID : 581

Sample(s) Submitted By : Universidad Metropolitana, UMET
Sampled By : Client
Sample(s) Log Number : 130426K001 to 130426K015
Date Received : 4/25/2013
Date Collected : 4/5/2013

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K001	Area C Sample 17	Mercury	S	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	S	EPA 6010	mg/kg	---	4	5/8/2013	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	S	EPA 6010	mg/kg	---	4.5	5/8/2013	pa
		Copper	S	EPA 6010	mg/kg	---	3.8	5/8/2013	pa
		Lead	S	EPA 6010	mg/kg	---	1	5/8/2013	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	S	EPA 6010	mg/kg	---	8.2	5/8/2013	pa
130426K002	Area C Sample 18	Mercury	S	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	S	EPA 6010	mg/kg	---	4	5/8/2013	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	S	EPA 6010	mg/kg	---	4.2	5/8/2013	pa
		Copper	S	EPA 6010	mg/kg	---	3.7	5/8/2013	pa
		Lead	S	EPA 6010	mg/kg	---	1	5/8/2013	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	S	EPA 6010	mg/kg	---	7.7	5/8/2013	pa

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Sanco Laboratories, Inc.
Sample(s) Log Number : 130426K001 to 130426K015

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K006	Area B Sample 4	Mercury	S	EPA 7471B	mg/kg	---	0.016	5/8/2013	pa
		Arsenic	S	EPA 6010	mg/kg	---	3	5/8/2013	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	S	EPA 6010	mg/kg	---	6.1	5/8/2013	pa
		Copper	S	EPA 6010	mg/kg	---	5.5	5/8/2013	pa
		Lead	S	EPA 6010	mg/kg	---	1	5/8/2013	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	S	EPA 6010	mg/kg	---	9.4	5/8/2013	pa
130426K007	Area B Sample 5	Mercury	S	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	S	EPA 6010	mg/kg	---	3	5/8/2013	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	S	EPA 6010	mg/kg	---	5.7	5/8/2013	pa
		Copper	S	EPA 6010	mg/kg	---	5.0	5/8/2013	pa
		Lead	S	EPA 6010	mg/kg	---	1	5/8/2013	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	S	EPA 6010	mg/kg	---	8.2	5/8/2013	pa

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K008	Area B Sample 6	Mercury	S	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	S	EPA 6010	mg/kg	---	4	5/8/2013	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	S	EPA 6010	mg/kg	---	4.3	5/8/2013	pa
		Copper	S	EPA 6010	mg/kg	---	10.8	5/8/2013	pa
		Lead	S	EPA 6010	mg/kg	---	1	5/8/2013	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	S	EPA 6010	mg/kg	---	9.3	5/8/2013	pa
130426K009	Area B Sample 7	Mercury	S	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	S	EPA 6010	mg/kg	---	2	5/8/2013	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	S	EPA 6010	mg/kg	---	7.3	5/8/2013	pa
		Copper	S	EPA 6010	mg/kg	---	8.6	5/8/2013	pa
		Lead	S	EPA 6010	mg/kg	---	3	5/8/2013	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	S	EPA 6010	mg/kg	---	19.6	5/8/2013	pa

Sanco Laboratories, Inc.
Sample(s) Log Number : 130426K001 to 130426K015

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K010	Area B Sample 8	Mercury	S	EPA 7471B	mg/kg	---	0.020	5/8/2013	pa
		Arsenic	S	EPA 6010	mg/kg	---	6	5/8/2013	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	S	EPA 6010	mg/kg	---	14.9	5/8/2013	pa
		Copper	S	EPA 6010	mg/kg	---	28.5	5/8/2013	pa
		Lead	S	EPA 6010	mg/kg	---	4	5/8/2013	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	S	EPA 6010	mg/kg	---	29.4	5/8/2013	pa
130426K011	Area A Sample 4	Mercury	S	EPA 7471B	mg/kg	---	0.020	5/8/2013	pa
		Arsenic	S	EPA 6010	mg/kg	---	4	5/8/2013	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	S	EPA 6010	mg/kg	---	9.7	5/8/2013	pa
		Copper	S	EPA 6010	mg/kg	---	12.2	5/8/2013	pa
		Lead	S	EPA 6010	mg/kg	---	3	5/8/2013	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	S	EPA 6010	mg/kg	---	20.0	5/8/2013	pa

Sanco Laboratories, Inc.
Sample(s) Log Number : 130426K001 to 130426K015

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K012	Area A Sample 5	Mercury	S	EPA 7471B	mg/kg	---	0.042	5/8/2013	pa
		Arsenic	S	EPA 6010	mg/kg	---	4	5/8/2013	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	S	EPA 6010	mg/kg	---	18.6	5/8/2013	pa
		Copper	S	EPA 6010	mg/kg	---	19.4	5/8/2013	pa
		Lead	S	EPA 6010	mg/kg	---	7	5/8/2013	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	S	EPA 6010	mg/kg	---	47.0	5/8/2013	pa
130426K013	Area A Sample 6	Mercury	S	EPA 7471B	mg/kg	---	0.018	5/8/2013	pa
		Arsenic	S	EPA 6010	mg/kg	---	7	5/8/2013	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	S	EPA 6010	mg/kg	---	23.8	5/8/2013	pa
		Copper	S	EPA 6010	mg/kg	---	16.1	5/8/2013	pa
		Lead	S	EPA 6010	mg/kg	---	2	5/8/2013	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	S	EPA 6010	mg/kg	---	20.3	5/8/2013	pa

Sanco Laboratories, Inc.
Sample(s) Log Number : 130426K001 to 130426K015

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K014	Area A Sample 7	Mercury	S	EPA 7471B	mg/kg	---	0.055	5/8/2013	pa
		Arsenic	S	EPA 6010	mg/kg	---	4	5/8/2013	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	S	EPA 6010	mg/kg	---	16.0	5/8/2013	pa
		Copper	S	EPA 6010	mg/kg	---	39.6	5/8/2013	pa
		Lead	S	EPA 6010	mg/kg	---	7	5/8/2013	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	S	EPA 6010	mg/kg	---	53.1	5/8/2013	pa
130426K015	Area A Sample 8	Mercury	S	EPA 7471B	mg/kg	---	0.059	5/8/2013	pa
		Arsenic	S	EPA 6010	mg/kg	---	4	5/8/2013	pa
		Cadmium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	S	EPA 6010	mg/kg	---	13.9	5/8/2013	pa
		Copper	S	EPA 6010	mg/kg	---	13.6	5/8/2013	pa
		Lead	S	EPA 6010	mg/kg	---	5	5/8/2013	pa
		Selenium	S	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	S	EPA 6010	mg/kg	---	29.1	5/8/2013	pa

S - Solid
ND - Not Detected

Revised by:

Lic. Enid Ortíz
Laboratory Supervisor

Released by:

Heriberto Batíz, Ph.D.
Technical Director

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Lic. # 568
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May 29, 2013

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LABORATORY REPORT

Project ID : 130426K016 **Customer ID** : 581
Project Description : Forest Service Study

Sample(s) Submitted By : Universidad Metropolitana, UMET **Date Received** : 4/25/2013
Sampled By : Client **Date Collected** : 4/5/2013
Sample(s) Log Number : 130426K016 to 130426K030

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K016	Area C C17-C21 MR / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
130426K017	Area C C17-C21 MR / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	2.0	5/8/2013	pa

Sanco Laboratories, Inc.
Sample(s) Log Number : 130426K016 to 130426K030

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K018	Area C C17-C21 MN / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	0.017	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	1.8	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	7.9	5/8/2013	pa
130426K019	Area C C17-C21 MN / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	0.037	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	2	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	1.1	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	7.1	5/8/2013	pa
130426K020	Area C C17-C21 MB / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	1.8	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	3.7	5/8/2013	pa

Sanco Laboratories, Inc.
Sample(s) Log Number : 130426K016 to 130426K030

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K021	Area C C17-C21 MB / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	2.6	5/8/2013	pa
130426K022	Area B B4-B6 MB / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
130426K023	Area B B4-B6 MB / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	1.6	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	3.9	5/8/2013	pa

Sanco Laboratories, Inc.
Sample(s) Log Number : 130426K016 to 130426K030

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K024	Area B B4-B6 MR / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	2.1	5/8/2013	pa
130426K025	Area B B4-B6 MR / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	1.9	5/8/2013	pa
130426K026	Area B B4-B6 MN / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	8.9	5/8/2013	pa

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K027	Area B B4-B6 MN / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	4.6	5/8/2013	pa
130426K028	Area B B7 MN / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	2.0	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	19.5	5/8/2013	pa
130426K029	Area B B7 MN / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	0.026	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	1	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	1.0	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	10.1	5/8/2013	pa

Sanco Laboratories, Inc.
Sample(s) Log Number : 130426K016 to 130426K030

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K030	Area B B7 MB / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	1.2	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	5.7	5/8/2013	pa

ND - Not Detected
MR - Mangle Rojo
MB - Mangle Blanco
MN - Mangle Negro
HV - Hoja Verde
HS - Hoja Senecente

Revised by:

Lic. Enid Ortíz
Laboratory Supervisor

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May 29, 2013

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LABORATORY REPORT

Project ID	: 130426K031	**Customer ID**	: 581
Project Description	: Forest Service Study		
Sample(s) Submitted By	: Universidad Metropolitana, UMET	**Date Received**	: 4/25/2013
Sampled By	: Client	**Date Collected**	: 4/7/2013
Sample(s) Log Number	: 130426K031 to 130426K045		

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K031	Area B B7 MB / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	0.024	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	6.0	5/8/2013	pa
130426K032	Area B B7 MR / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K033	Area B B7 MR / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	1.2	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	3.6	5/8/2013	pa
130426K034	Area A A4 MB / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	9.2	5/8/2013	pa

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K035	Area A A4 MB / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	6.3	5/8/2013	pa
130426K036	Area A A4 MN / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	2.5	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	17.6	5/8/2013	pa
130426K037	Area A A4 MN / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	0.020	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	2.1	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	8.7	5/8/2013	pa

Sanco Laboratories, Inc.
Sample(s) Log Number : 130426K031 to 130426K045

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K038	Area A A4 MR / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	1.7	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	3.3	5/8/2013	pa
130426K039	Area A A4 MR / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	3.1	5/8/2013	pa
130426K040	Area A A7 MN / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	2.5	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	7.6	5/8/2013	pa

Sanco Laboratories, Inc.
Sample(s) Log Number : 130426K031 to 130426K045

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K041	Area A A7 MN / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	2.5	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	7.6	5/8/2013	pa
130426K042	Area A A7 MB / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	4.1	5/8/2013	pa
130426K043	Area A A7 MB / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	7.7	5/8/2013	pa

Sanco Laboratories, Inc.
Sample(s) Log Number : 130426K031 to 130426K045

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130426K044	Area A A7 MR / HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	1.0	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	3.2	5/8/2013	pa
130426K045	Area A A7 MR / HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	1.3	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	4.8	5/8/2013	pa

ND - Not Detected
MR - Mangle Rojo
MB - Mangle Blanco
MN - Mangle Negro
HV - Hoja Verde
HS - Hoja Senecente

Revised by:

Lic. Enid Ortíz
Laboratory Supervisor

Released by:

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May 30, 2013

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LABORATORY REPORT

Project ID : 130430I001
Project Description : Forest Service Study
Customer ID : 581

Sample(s) Submitted By : Universidad Metropolitana, UMET
Sampled By : Client
Sample(s) Log Number : 130430I001 to 130430I012
Date Received : 4/29/2013
Date Collected : 4/27/2013

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130430I001	Area C1-C10 MR/HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	2.3	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	2.0	5/8/2013	pa
130430I002	Area C1-C10 MR/HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa

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Sanco Laboratories, Inc.
Sample(s) Log Number : 130430I001 to 130430I012

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130430I003	Area C1-C10 MB/HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	2.2	5/8/2013	pa
130430I004	Area C1-C10 MB/HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	4.0	5/8/2013	pa
130430I005	Area C1-C10 MN/HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	8.9	5/8/2013	pa

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
1304301006	Area C1-C10 MN/HS	Mercury	Leaves	EPA 7471B	mg/kg	---	0.024	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	6.4	5/8/2013	pa
1304301007	Area C11-C16 MR/HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	1.8	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
1304301008	Area C11-C16 MR/HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	2.6	5/8/2013	pa

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
130430I009	Area C11-C16 MB/HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	1.1	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	1	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	3.4	5/8/2013	pa
130430I010	Area C11-C16 MB/HS	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	8.4	5/8/2013	pa
130430I011	Area C11-C16 MN/HV	Mercury	Leaves	EPA 7471B	mg/kg	---	ND	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	4.8	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	10.4	5/8/2013	pa

Sanco Laboratories, Inc.
Sample(s) Log Number : 1304301001 to 1304301012

Log Number	Description	Parameter	Sample Type	Method	Units	Limit	Result	Date Analyzed	Analyst
1304301012	Area C11-C16 MN/HS	Mercury	Leaves	EPA 7471B	mg/kg	---	0.022	5/8/2013	pa
		Arsenic	Leaves	EPA 6010	mg/kg	---	1	5/8/2013	pa
		Cadmium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Chromium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Copper	Leaves	EPA 6010	mg/kg	---	2.1	5/8/2013	pa
		Lead	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Selenium	Leaves	EPA 6010	mg/kg	---	ND	5/8/2013	pa
		Zinc	Leaves	EPA 6010	mg/kg	---	7.8	5/8/2013	pa

ND - Not Detected
MR - Mangle Rojo
MB - Mangle Blanco
MN - Mangle Negro
HV - Hoja Verde
HS - Hoja Senecente

Revised by:

Lic. Enid Ortiz
Laboratory Supervisor

ESTADO LIBRE ASOCIADO DE PUERTO RICO
QUIMICO LICENCIADO
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Lic. # 568
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Released by:

Heriberto Batíz, Ph.D.
Technical Director

APPENDIX 2

STATISTICAL ANALYSIS FOR LEAVES DATA USING MINITAB PROGRAM

3/1/2014 1:28:07 PM

Welcome to Minitab, press F1 for help.

RETRANSLOCATION

Descriptive Statistics: Arsenic Gree, Cadmium Gree, Chromium Gre, ... Zona C

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1
Arsenic Green	3	0	0.8443	0.0452	0.0783	0.7543	0.7543
Cadmium Green	3	0	0.4761	0.0401	0.0694	0.4310	0.4310
Chromium Green	3	0	0.8803	0.0100	0.0173	0.8620	0.8620
Copper Green	3	0	1.610	0.262	0.454	1.238	1.238
Lead Green	3	0	0.4876	0.0429	0.0743	0.4413	0.4413
Mercury Green	3	0	0.017975	0.000525	0.000909	0.016925	0.016925
Zinc Green	3	0	4.46	1.71	2.97	1.83	1.83
Arsenic Brown	3	0	0.970	0.120	0.208	0.842	0.842
Cadmium Brown	3	0	0.43200	0.00728	0.01260	0.42100	0.42100
Chromium Brown	3	0	0.8638	0.0146	0.0253	0.8418	0.8418
Copper Brown	3	0	0.987	0.137	0.237	0.842	0.842
Lead Brown	3	0	0.43450	0.00967	0.01675	0.42100	0.42100
Mercury Brown	3	0	0.02128	0.00278	0.00482	0.01835	0.01835
Zinc Brown	3	0	4.36	1.29	2.24	1.97	1.97

Variable	Median	Q3	Maximum
Arsenic Green	0.8823	0.8965	0.8965
Cadmium Green	0.4413	0.5560	0.5560
Chromium Green	0.8823	0.8965	0.8965
Copper Green	1.476	2.116	2.116
Lead Green	0.4483	0.5733	0.5733
Mercury Green	0.018500	0.018500	0.018500
Zinc Green	3.87	7.68	7.68
Arsenic Brown	0.858	1.211	1.211
Cadmium Brown	0.42925	0.44575	0.44575
Chromium Brown	0.8583	0.8915	0.8915
Copper Brown	0.858	1.261	1.261
Lead Brown	0.42925	0.45325	0.45325
Mercury Brown	0.01865	0.02685	0.02685
Zinc Brown	4.73	6.40	6.40

One-way ANOVA: Arsenic Gree, Cadmium Gree, Chromium Gre, Copper Green, ...

Source	DF	SS	MS	F	P
Factor	13	78.71	6.05	6.00	0.000
Error	28	28.25	1.01		
Total	41	106.96			

S = 1.004   R-Sq = 73.59%   R-Sq(adj) = 61.32%

```
                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level           N   Mean  StDev  ------+---------+---------+---------+---
Arsenic Green   3  0.844  0.078      (-----*-----)
Cadmium Green   3  0.476  0.069   (-----*-----)
Chromium Green  3  0.880  0.017      (-----*-----)
Copper Green    3  1.610  0.454         (-----*-----)
Lead Green      3  0.488  0.074   (-----*-----)
Mercury Green   3  0.018  0.001  (-----*-----)
Zinc Green      3  4.459  2.967                    (-----*-----)
Arsenic Brown   3  0.970  0.208      (-----*-----)
Cadmium Brown   3  0.432  0.013   (-----*-----)
Chromium Brown  3  0.864  0.025      (-----*-----)
Copper Brown    3  0.987  0.237      (-----*-----)
Lead Brown      3  0.435  0.017   (-----*-----)
Mercury Brown   3  0.021  0.005  (-----*-----)
Zinc Brown      3  4.364  2.236                    (-----*-----)
                         ------+---------+---------+---------+---
                             0.0       2.0       4.0       6.0
```

Pooled StDev = 1.004

One-way ANOVA: Arsenic Green, Arsenic Brown Area C

Source	DF	SS	MS	F	P
Factor	1	0.0238	0.0238	0.96	0.383
Error	4	0.0991	0.0248		
Total	5	0.1228			

S = 0.1574   R-Sq = 19.34%   R-Sq(adj) = 0.00%

```
                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level          N    Mean   StDev  ---+---------+---------+---------+------
Arsenic Green  3  0.8443  0.0783  (---------------*---------------)
Arsenic Brown  3  0.9702  0.2083        (---------------*--------------)
                         ---+---------+---------+---------+------
                           0.64      0.80      0.96      1.12
```

Pooled StDev = 0.1574

One-way ANOVA: Cadmium Green, Cadmium Brown Area C

Source	DF	SS	MS	F	P
Factor	1	0.00292	0.00292	1.17	0.340
Error	4	0.00995	0.00249		
Total	5	0.01287			

S = 0.04988   R-Sq = 22.66%   R-Sq(adj) = 3.32%

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level          N    Mean    StDev   -+---------+---------+---------+--------
Cadmium Green  3  0.47608  0.06940          (------------*-------------)
Cadmium Brown  3  0.43200  0.01260  (------------*------------)
                                    -+---------+---------+---------+--------
                                    0.360     0.420     0.480     0.540
```

Pooled StDev = 0.04988

One-way ANOVA: Chromium Green, Chromium Brown Area C

Source	DF	SS	MS	F	P
Factor	1	0.000404	0.000404	0.86	0.407
Error	4	0.001885	0.000471		
Total	5	0.002290			

S = 0.02171   R-Sq = 17.66%   R-Sq(adj) = 0.00%

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level           N    Mean    StDev  --------+---------+---------+---------+-
Chromium Green  3  0.88025  0.01734       (-------------*-------------)
Chromium Brown  3  0.86383  0.02534  (-------------*------------)
                                    --------+---------+---------+---------+-
                                          0.850     0.875     0.900     0.925
```

Pooled StDev = 0.02171

One-way ANOVA: Lead Green, Lead Brown Area C

Source	DF	SS	MS	F	P
Factor	1	0.00423	0.00423	1.46	0.294
Error	4	0.01159	0.00290		
Total	5	0.01582			

S = 0.05384   R-Sq = 26.72%   R-Sq(adj) = 8.40%

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level       N     Mean    StDev  --+---------+---------+---------+-------
Lead Green  3  0.48758  0.07427          (-------------*--------------)
Lead Brown  3  0.43450  0.01675  (-------------*--------------)
                                 --+---------+---------+---------+-------
                                 0.360     0.420     0.480     0.540
```

Pooled StDev = 0.05384

One-way ANOVA: Mercury Green, Mercury Brown Area C

Source	DF	SS	MS	F	P
Factor	1	0.0000164	0.0000164	1.36	0.308
Error	4	0.0000482	0.0000120		
Total	5	0.0000646			

S = 0.003471   R-Sq = 25.42%   R-Sq(adj) = 6.77%

Level	N	Mean	StDev
Mercury Green	3	0.017975	0.000909
Mercury Brown	3	0.021283	0.004823

```
               Individual 95% CIs For Mean Based on Pooled
               StDev
Level          ---------+---------+---------+---------+
Mercury Green  (-------------*-------------)
Mercury Brown        (-------------*-------------)
               ---------+---------+---------+---------+
                    0.0160    0.0200    0.0240    0.0280
```

Pooled StDev = 0.003471

One-way ANOVA: Zinc Green, Zinc Brown Area C

Source	DF	SS	MS	F	P
Factor	1	0.01	0.01	0.00	0.967
Error	4	27.60	6.90		
Total	5	27.62			

S = 2.627   R-Sq = 0.05%   R-Sq(adj) = 0.00%

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level       N  Mean  StDev  ---------+---------+---------+---------+
Zinc Green  3  4.459  2.967  (----------------*----------------)
Zinc Brown  3  4.364  2.236  (---------------*----------------)
                          ---------+---------+---------+---------+
                                 2.5       5.0       7.5      10.0
```

Pooled StDev = 2.627

One-way ANOVA: Copper Green, Copper Brown Area C

Source	DF	SS	MS	F	P
Factor	1	0.582	0.582	4.44	0.103
Error	4	0.524	0.131		
Total	5	1.107			

S = 0.3620   R-Sq = 52.62%   R-Sq(adj) = 40.78%

```
                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level         N    Mean   StDev  --+---------+---------+---------+-------
Copper Green  3  1.6099  0.4538            (----------*-----------)
Copper Brown  3  0.9868  0.2371  (-----------*----------)
                              --+---------+---------+---------+-------
                              0.50      1.00      1.50      2.00
```

Pooled StDev = 0.3620

Paired T-Test and CI: Metals Green, Metals Brown, Area C, Red Mangle

Paired T for Metals Brown - Metals Green

	N	Mean	StDev	SE Mean
Arsenic Brown	7	0.765129	0.614194	0.232144
Arsenic Green	7	0.853464	0.630481	0.238299
Difference	7	-0.088336	0.248655	0.093983

95% CI for mean difference: (-0.318303, 0.141631)
T-Test of mean difference = 0 (vs not = 0): T-Value = -0.94 P-Value = 0.384

Paired T-Test and CI: Metals Green, Metals Brown, Area C, Black Mangle

Paired T for Metsls Brown - Metals Green

	N	Mean	StDev	SE Mean
Arsenic Brown	7	1.52655	2.19353	0.82907
Arsenic Green	7	1.80103	2.67181	1.00985
Difference	7	-0.274475	0.570522	0.215637

95% CI for mean difference: (-0.802119, 0.253169)
T-Test of mean difference = 0 (vs not = 0): T-Value = -1.27 P-Value = 0.250

Paired T-Test and CI: Metals Green, Metals Brown, Area C, White Mangle

Paired T for Metals Brown - Metals Green

	N	Mean	StDev	SE Mean
Arsenic Brown	7	1.16809	1.59965	0.60461
Arsenic Green	7	1.10636	1.27467	0.48178
Difference	7	0.061729	0.440030	0.166316

95% CI for mean difference: (-0.345232, 0.468689)
T-Test of mean difference = 0 (vs not = 0): T-Value = 0.37 P-Value = 0.723

Descriptive Statistics: Arsenic Gree, Cadmium Gree, Chromium Gre, ... Area B

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1
Arsenic Green	3	0	0.8919	0.0104	0.0181	0.8723	0.8723
Cadmium Green	3	0	0.44589	0.00527	0.00913	0.43600	0.43600
Chromium Green	3	0	0.8919	0.0104	0.0181	0.8723	0.8723
Copper Green	3	0	1.205	0.159	0.276	0.908	0.908
Lead Green	3	0	0.44589	0.00527	0.00913	0.43600	0.43600
Mercury Green	3	0	0.017856	0.000594	0.001029	0.017133	0.017133
Zinc Green	3	0	5.33	2.21	3.83	1.94	1.94
Arsenic Brown	3	0	0.8634	0.0469	0.0812	0.7970	0.7970
Cadmium Brown	3	0	0.4240	0.0162	0.0281	0.3983	0.3983
Chromium Brown	3	0	0.8481	0.0323	0.0560	0.7970	0.7970
Copper Brown	3	0	0.988	0.122	0.211	0.797	0.797
Lead Brown	3	0	0.4319	0.0237	0.0411	0.3983	0.3983
Mercury Brown	3	0	0.02153	0.00260	0.00450	0.01713	0.01713
Zinc Brown	3	0	5.54	1.76	3.05	2.36	2.36

Variable	Median	Q3	Maximum
Arsenic Green	0.8953	0.9080	0.9080
Cadmium Green	0.44767	0.45400	0.45400
Chromium Green	0.8953	0.9080	0.9080
Copper Green	1.254	1.454	1.454
Lead Green	0.44767	0.45400	0.45400
Mercury Green	0.017400	0.019033	0.019033
Zinc Green	4.56	9.48	9.48
Arsenic Brown	0.8393	0.9540	0.9540
Cadmium Brown	0.4197	0.4540	0.4540
Chromium Brown	0.8393	0.9080	0.9080
Copper Brown	0.952	1.214	1.214
Lead Brown	0.4197	0.4777	0.4777
Mercury Brown	0.02133	0.02613	0.02613
Zinc Brown	5.80	8.45	8.45

One-way ANOVA: Arsenic Green, Arsenic Brown, Area B

Source	DF	SS	MS	F	P
Factor	1	0.001734	0.001734	2.22	0.211
Error	4	0.003128	0.000782		
Total	5	0.004862			

S = 0.02797   R-Sq = 35.66%   R-Sq(adj) = 19.58%

```
                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level          N    Mean   StDev   -+---------+---------+---------+--------
Arsenic Green  3  0.84533  0.02806  (------------*-----------)
Arsenic Brown  3  0.87933  0.02787         (------------*------------)
                                   -+---------+---------+---------+--------
                                   0.805     0.840     0.875     0.910
```

Pooled StDev = 0.02797

One-way ANOVA: Cadmium Green, Cadmium Brown, Area B

Source	DF	SS	MS	F	P
Factor	1	0.000433	0.000433	2.22	0.210
Error	4	0.000780	0.000195		
Total	5	0.001214			

S = 0.01397   R-Sq = 35.71%   R-Sq(adj) = 19.64%

```
                               Individual 95% CIs For Mean Based on
                               Pooled StDev
Level          N    Mean   StDev   +---------+---------+---------+---------
Cadmium Green  3  0.42278  0.01408   (-------------*-------------)
Cadmium Brown  3  0.43978  0.01385            (-------------*-------------)
                                   +---------+---------+---------+---------
                                 0.400     0.416     0.432     0.448
```

Pooled StDev = 0.01397

One-way ANOVA: Chromium Green, Chromium Brown, Area B

Source	DF	SS	MS	F	P
Factor	1	0.001734	0.001734	2.22	0.211
Error	4	0.003128	0.000782		
Total	5	0.004862			

S = 0.02797   R-Sq = 35.66%   R-Sq(adj) = 19.58%

```
                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level           N    Mean   StDev  -+---------+---------+---------+--------
Chromium Green  3  0.84533  0.02806  (------------*-----------)
Chromium Brown  3  0.87933  0.02787          (------------*------------)
                                   -+---------+---------+---------+--------
                                  0.805     0.840     0.875     0.910
```

Pooled StDev = 0.02797

One-way ANOVA: Copper Green, Copper Brown, Area B

```
Source  DF     SS     MS     F      P
Factor   1  0.246  0.246  0.27  0.634
Error    4  3.705  0.926
Total    5  3.950

S = 0.9624   R-Sq = 6.22%   R-Sq(adj) = 0.00%


                            Individual 95% CIs For Mean Based on
                            Pooled StDev

Level          N    Mean   StDev  ---+---------+---------+---------+------
Copper Green  3  1.2894  0.4497  (---------------*--------------)
Copper Brown  3  1.6943  1.2845       (--------------*--------------)
                            ---+---------+---------+---------+------
                             0.0       1.0       2.0       3.0

Pooled StDev = 0.9624
```

One-way ANOVA: Lead Green, Lead Brown, Area B

```
Source  DF        SS        MS     F      P
Factor   1  0.002128  0.002128  2.62  0.181
Error    4  0.003247  0.000812
Total    5  0.005375

S = 0.02849   R-Sq = 39.60%   R-Sq(adj) = 24.49%


                            Individual 95% CIs For Mean Based on
                            Pooled StDev

Level       N     Mean    StDev  --+---------+---------+---------+-------
Lead Green  3  0.42278  0.01408  (------------*------------)
Lead Brown  3  0.46044  0.03775            (------------*------------)
                            --+---------+---------+---------+-------
                            0.385     0.420     0.455     0.490

Pooled StDev = 0.02849
```

One-way ANOVA: Mercury Green, Mercury Brown, Area B

Source	DF	SS	MS	F	P
Factor	1	0.0000311	0.0000311	1.99	0.231
Error	4	0.0000626	0.0000157		
Total	5	0.0000938			

S = 0.003957   R-Sq = 33.20%   R-Sq(adj) = 16.50

Level	N	Mean	StDev
Mercury Green	3	0.017267	0.000353
Mercury Brown	3	0.021822	0.005585

```
              Individual 95% CIs For Mean Based on
              Pooled StDev

Level         --------+---------+---------+---------+-
Mercury Green  (------------*-----------)
Mercury Brown         (------------*-----------)
              --------+---------+---------+---------+-
                   0.0150    0.0200    0.0250    0.0300
```

Pooled StDev = 0.003957

One-way ANOVA: Zinc Green, Zinc Brown, Area B

Source	DF	SS	MS	F	P
Factor	1	2.2	2.2	0.14	0.727
Error	4	61.4	15.4		
Total	5	63.6			

S = 3.918   R-Sq = 3.39%   R-Sq(adj) = 0.00%

```
                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level       N   Mean  StDev  --+---------+---------+---------+-------
Zinc Green  3  6.928  4.900      (-----------------*-----------------)
Zinc Brown  3  5.729  2.586  (-----------------*-----------------)
                             --+---------+---------+---------+-------
                               0.0       3.5       7.0      10.5
```

Pooled StDev = 3.918

Paired T-Test and CI: Metals Green, Metals Brown, Area A, Red Mangle

Paired T for Metals Green – Metals Brown

	N	Mean	StDev	SE Mean
Arsenic Green	7	0.923638	0.900456	0.340340
Arsenic Brown	7	0.991114	1.099193	0.415456
Difference	7	-0.067476	0.241691	0.091351

95% CI for mean difference: (-0.291004, 0.156051)
T-Test of mean difference = 0 (vs not = 0): T-Value = -0.74 P-Value = 0.488

Paired T-Test and CI: Metals Green, Metals Brown, Area A, Black Mangle

Paired T for Metals Green - Metsls Brown

	N	Mean	StDev	SE Mean
Arsenic Green	7	2.39500	4.41694	1.66945
Arsenic Brown	7	2.05575	3.01589	1.13990
Difference	7	0.339248	1.628822	0.615637

95% CI for mean difference: (-1.167161, 1.845656)
T-Test of mean difference = 0 (vs not = 0): T-Value = 0.55 P-Value = 0.601

Paired T-Test and CI: Metals Green, Metals Brown, Area A, White Mangle

Paired T for Metals Green - Metals Brown

	N	Mean	StDev	SE Mean
Cadmium Green	7	1.29738	1.95524	0.73901
Cadmium Brown	7	1.28339	1.81663	0.68662
Difference	7	0.013990	0.146702	0.055448

95% CI for mean difference: (-0.121686, 0.149667)
T-Test of mean difference = 0 (vs not = 0): T-Value = 0.25 P-Value = 0.809

Descriptive Statistics: Arsenic Gree, Cadmium Gree, Chromium Gre, ... Area A

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1
Arsenic Green	3	0	0.8453	0.0162	0.0281	0.8273	0.8273
Cadmium Green	3	0	0.42278	0.00813	0.01408	0.41367	0.41367
Chromium Green	3	0	0.8453	0.0162	0.0281	0.8273	0.8273
Copper Green	3	0	1.289	0.260	0.450	0.898	0.898
Lead Green	3	0	0.42278	0.00813	0.01408	0.41367	0.41367
Mercury Green	3	0	0.017267	0.000204	0.000353	0.017000	0.017000
Zinc Green	3	0	6.93	2.83	4.90	2.78	2.78
Arsenic Brown	3	0	0.8793	0.0161	0.0279	0.8523	0.8523
Cadmium Brown	3	0	0.43978	0.00800	0.01385	0.42633	0.42633
Chromium Brown	3	0	0.8793	0.0161	0.0279	0.8523	0.8523
Copper Brown	3	0	1.694	0.742	1.285	0.908	0.908
Lead Brown	3	0	0.4604	0.0218	0.0377	0.4263	0.4263
Mercury Brown	3	0	0.02182	0.00322	0.00558	0.01840	0.01840
Zinc Brown	3	0	5.73	1.49	2.59	3.36	3.36

Variable	Median	Q3	Maximum
Arsenic Green	0.8310	0.8777	0.8777
Cadmium Green	0.41567	0.43900	0.43900
Chromium Green	0.8310	0.8777	0.8777
Copper Green	1.190	1.781	1.781
Lead Green	0.41567	0.43900	0.43900
Mercury Green	0.017133	0.017667	0.017667
Zinc Green	5.67	12.33	12.33
Arsenic Brown	0.8777	0.9080	0.9080
Cadmium Brown	0.43900	0.45400	0.45400
Chromium Brown	0.8777	0.9080	0.9080
Copper Brown	0.998	3.177	3.177
Lead Brown	0.4540	0.5010	0.5010
Mercury Brown	0.01880	0.02827	0.02827
Zinc Brown	5.33	8.49	8.49

One-way ANOVA: Arsenic Green, Arsenic Brown, Area A

Source	DF	SS	MS	F	P
Factor	1	0.00121	0.00121	0.35	0.586
Error	4	0.01385	0.00346		
Total	5	0.01506			

S = 0.05884   R-Sq = 8.06%   R-Sq(adj) = 0.00%

```
                                 Individual 95% CIs For Mean Based on
                                 Pooled StDev
Level          N    Mean   StDev  --+---------+---------+---------+-------
Arsenic Green  3  0.89189  0.01808       (---------------*--------------)
Arsenic Brown  3  0.86344  0.08123  (---------------*---------------)
                                  --+---------+---------+---------+-------
                                  0.780     0.840     0.900     0.960
```

Pooled StDev = 0.05884

One-way ANOVA: Cadmium Green, Cadmium Brown Area A

```
Source  DF        SS        MS     F      P
Factor   1  0.000719  0.000719  1.65  0.269
Error    4  0.001744  0.000436
Total    5  0.002463

S = 0.02088   R-Sq = 29.18%   R-Sq(adj) = 11.47%


                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level           N     Mean    StDev  ----+---------+---------+---------+-----
Cadmium Green   3  0.44589  0.00913          (------------*-------------)
Cadmium Brown   3  0.42400  0.02809  (-------------*------------)
                                     ----+---------+---------+---------+-----
                                       0.400     0.425     0.450     0.475

Pooled StDev = 0.02088
```

One-way ANOVA: Chromium Green, Chromium Brown Area A

```
Source  DF       SS       MS     F      P
Factor   1  0.00287  0.00287  1.66  0.267
Error    4  0.00693  0.00173
Total    5  0.00980

S = 0.04162   R-Sq = 29.32%   R-Sq(adj) = 11.65%


                                 Individual 95% CIs For Mean Based on
                                 Pooled StDev
Level            N     Mean    StDev  ----+---------+---------+---------+-----
Chromium Green   3  0.89189  0.01808          (------------*-------------)
Chromium Brown   3  0.84811  0.05602  (-------------*------------)
                                      ----+---------+---------+---------+-----
                                        0.800     0.850     0.900     0.950

Pooled StDev = 0.04162
```

One-way ANOVA: Copper Green, Copper Brown Area A

Source	DF	SS	MS	F	P
Factor	1	0.0711	0.0711	1.18	0.339
Error	4	0.2415	0.0604		
Total	5	0.3125			

S = 0.2457   R-Sq = 22.74%   R-Sq(adj) = 3.42%

```
                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level          N    Mean   StDev   +---------+---------+---------+---------
Copper Green   3  1.2053  0.2762         (------------*------------)
Copper Brown   3  0.9877  0.2108   (------------*------------)
                                   +---------+---------+---------+---------
                                 0.60      0.90      1.20      1.50
```

Pooled StDev = 0.2457

One-way ANOVA: Lead Green, Lead Brown Area A

Source	DF	SS	MS	F	P
Factor	1	0.000294	0.000294	0.33	0.595
Error	4	0.003538	0.000884		
Total	5	0.003832			

S = 0.02974   R-Sq = 7.67%   R-Sq(adj) = 0.00%

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level       N     Mean    StDev  --+---------+---------+---------+-------
Lead Green  3  0.44589  0.00913      (---------------*---------------)
Lead Brown  3  0.43189  0.04105  (---------------*---------------)
                                 --+---------+---------+---------+-------
                                 0.390     0.420     0.450     0.480
```

Pooled StDev = 0.02974

One-way ANOVA: Mercury Green, Mercury Brown Area A

Source	DF	SS	MS	F	P
Factor	1	0.0000203	0.0000203	1.90	0.240
Error	4	0.0000427	0.0000107		
Total	5	0.0000630			

S = 0.003266   R-Sq = 32.22%   R-Sq(adj) = 15.28%

Level	N	Mean	StDev
Mercury Green	3	0.017856	0.001029
Mercury Brown	3	0.021533	0.004503

```
              Individual 95% CIs For Mean Based on
              Pooled StDev
Level          --------+---------+---------+---------+-
Mercury Green  (------------*------------)
Mercury Brown           (------------*------------)
               --------+---------+---------+---------+-
                   0.0160    0.0200    0.0240    0.0280
```

Pooled StDev = 0.003266

One-way ANOVA: Zinc Green, Zinc Brown Area A

Source	DF	SS	MS	F	P
Factor	1	0.1	0.1	0.01	0.944
Error	4	47.9	12.0		
Total	5	48.0			

S = 3.462   R-Sq = 0.14%   R-Sq(adj) = 0.00%

```
                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level       N   Mean  StDev   -+---------+---------+---------+--------
Zinc Green  3  5.327  3.828   (-----------------*-----------------)
Zinc Brown  3  5.537  3.052    (-----------------*------------------)
                              -+---------+---------+---------+--------
                              0.0       3.0       6.0       9.0
```

Pooled StDev = 3.462

Paired T-Test and CI: Metals Green, Metals Brown, Area B, Red Mangle

Paired T for Metals Green - Metals Brown

	N	Mean	StDev	SE Mean
Arsenic Green	7	0.798486	0.603665	0.228164
Arsenic Brown	7	0.835781	0.748714	0.282987
Difference	7	-0.037295	0.174737	0.066044

95% CI for mean difference: (-0.198900, 0.124310)
T-Test of mean difference = 0 (vs not = 0): T-Value = -0.56 P-Value = 0.593

Paired T-Test and CI: Metals Green, Metals Brown, Area B, Back Mangle

Paired T for Metals Green - Metals Brown

	N	Mean	StDev	SE Mean
Arsenic Green	7	1.93853	3.35613	1.26850
Arsenic Brown	7	1.78340	2.96598	1.12104
Difference	7	0.155129	0.400020	0.151194

95% CI for mean difference: (-0.214829, 0.525086)
T-Test of mean difference = 0 (vs not = 0): T-Value = 1.03 P-Value = 0.344

Paired T-Test and CI: Metals Green, Metals Brown, Area B, White Mangle

Paired T for Metals Green - Metals Brown

	N	Mean	StDev	SE Mean
Arsenic Green	7	1.21673	1.52793	0.57750
Arsenic Brown	7	1.28652	2.00992	0.75968
Difference	7	-0.069790	0.536706	0.202856

95% CI for mean difference: (-0.566161, 0.426580)
T-Test of mean difference = 0 (vs not = 0): T-Value = -0.34 P-Value = 0.743

No hay una diferencia estadísticamente significativa entre el metal acumulado en la hoja verde y marron por metal por todos los tipos de mangle.

BIOACCUMULATION

Descriptive Statistics: Arsenic Gree, Cadmium Gree, Chromium Gre, ... Zona C

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median
Arsenic Green	3	0	0.17472	0.00936	0.01621	0.15608	0.15608	0.18257
Cadmium Green	3	0	23.51	1.98	3.43	21.28	21.28	21.79
Chromium Green	3	0	0.17007	0.00193	0.00335	0.16654	0.16654	0.17046
Copper Green	3	0	0.3488	0.0568	0.0983	0.2682	0.2682	0.3198
Lead Green	3	0	0.8655	0.0761	0.1318	0.7833	0.7833	0.7957
Mercury Green	3	0	2.8494	0.0832	0.1441	2.6830	2.6830	2.9326
Zinc Green	3	0	0.571	0.219	0.380	0.235	0.235	0.495
Arsenic Brown	3	0	0.2008	0.0249	0.0431	0.1742	0.1742	0.1776
Cadmium Brown	3	0	21.333	0.359	0.622	20.790	20.790	21.198
Chromium Brown	3	0	0.16690	0.00283	0.00490	0.16263	0.16263	0.16582
Copper Brown	3	0	0.2138	0.0297	0.0514	0.1824	0.1824	0.1859
Lead Brown	3	0	0.7713	0.0172	0.0297	0.7473	0.7473	0.7620
Mercury Brown	3	0	3.374	0.441	0.765	2.909	2.909	2.956
Zinc Brown	3	0	0.559	0.165	0.286	0.252	0.252	0.605

Variable	Q3	Maximum
Arsenic Green	0.18551	0.18551
Cadmium Green	27.46	27.46
Chromium Green	0.17321	0.17321
Copper Green	0.4583	0.4583
Lead Green	1.0176	1.0176
Mercury Green	2.9326	2.9326
Zinc Green	0.983	0.983
Arsenic Brown	0.2505	0.2505
Cadmium Brown	22.012	22.012
Chromium Brown	0.17224	0.17224
Copper Brown	0.2731	0.2731
Lead Brown	0.8046	0.8046
Mercury Brown	4.256	4.256
Zinc Brown	0.819	0.819

One-way ANOVA: Arsenic Green, Arsenic Brown Zona C

Source	DF	SS	MS	F	P
Factor	1	0.00102	0.00102	0.96	0.383
Error	4	0.00424	0.00106		
Total	5	0.00526			

S = 0.03256   R-Sq = 19.34%   R-Sq(adj) = 0.00%

```
                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level          N    Mean    StDev  -----+---------+---------+---------+----
Arsenic Green  3  0.17472  0.01621  (--------------*--------------)
Arsenic Brown  3  0.20076  0.04310         (--------------*--------------)
                                -----+---------+---------+---------+----
                                  0.140     0.175     0.210     0.245
```

Pooled StDev = 0.03256

One-way ANOVA: Cadmium Green, Cadmium Brown Zona C

Source	DF	SS	MS	F	P
Factor	1	7.11	7.11	1.17	0.340
Error	4	24.27	6.07		
Total	5	31.37			

S = 2.463   R-Sq = 22.66%   R-Sq(adj) = 3.32%

```
                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level          N    Mean  StDev   --+---------+---------+---------+-------
Cadmium Green  3  23.510  3.427          (------------*-------------)
Cadmium Brown  3  21.333  0.622   (------------*------------)
                                  --+---------+---------+---------+-------
                                  18.0      21.0      24.0      27.0
```

Pooled StDev = 2.463

One-way ANOVA: Chromium Green, Chromium Brown Zona C

Source	DF	SS	MS	F	P
Factor	1	0.0000151	0.0000151	0.86	0.407
Error	4	0.0000704	0.0000176		
Total	5	0.0000855			

S = 0.004195   R-Sq = 17.66%   R-Sq(adj) = 0.00%

```
                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level           N     Mean    StDev    +---------+---------+---------+---------
Chromium Green  3  0.17007  0.00335           (------------*-------------)
Chromium Brown  3  0.16690  0.00490    (-------------*------------)
                                       +---------+---------+---------+---------
                                     0.1600    0.1650    0.1700    0.1750
```

Pooled StDev = 0.00419

One-way ANOVA: Copper Green, Copper Brown Zona C

Source	DF	SS	MS	F	P
Factor	1	0.02733	0.02733	4.44	0.103
Error	4	0.02461	0.00615		
Total	5	0.05194			

S = 0.07843   R-Sq = 52.62%   R-Sq(adj) = 40.78%

```
                             Individual 95% CIs For Mean Based on
                             Pooled StDev
Level         N     Mean     StDev   -+---------+---------+---------+--------
Copper Green  3  0.34878  0.09831              (------------*-----------)
Copper Brown  3  0.21379  0.05138   (-----------*------------)
                                     -+---------+---------+---------+--------
                                     0.10      0.20      0.30      0.40
```

Pooled StDev = 0.07843

One-way ANOVA: Lead Green, Lead Brown Zona C

Source	DF	SS	MS	F	P
Factor	1	0.01332	0.01332	1.46	0.294
Error	4	0.03653	0.00913		
Total	5	0.04985			

S = 0.09557   R-Sq = 26.72%   R-Sq(adj) = 8.40%

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level       N    Mean   StDev  --------+---------+---------+---------+-
Lead Green  3  0.8655  0.1318        (------------*------------)
Lead Brown  3  0.7713  0.0297  (-----------*------------)
                               --------+---------+---------+---------+-
                                     0.72      0.84      0.96      1.08
```

Pooled StDev = 0.0956

One-way ANOVA: Mercury Green, Mercury Brown Zona C

```
Source  DF     SS     MS     F      P
Factor   1  0.413  0.413  1.36  0.308
Error    4  1.211  0.303
Total    5  1.623

S = 0.5502   R-Sq = 25.42%   R-Sq(adj) = 6.77%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level          N    Mean   StDev  -------+---------+---------+---------+--
Mercury Green  3  2.8494  0.1441  (-------------*--------------)
Mercury Brown  3  3.3738  0.7646           (-------------*--------------)
                           -------+---------+---------+---------+--
                               2.40      3.00      3.60      4.20

Pooled StDev = 0.5502
```

One-way ANOVA: Zinc Green, Zinc Brown Zona C

```
Source  DF     SS     MS     F      P
Factor   1  0.000  0.000  0.00  0.967
Error    4  0.452  0.113
Total    5  0.452

S = 0.3363   R-Sq = 0.05%   R-Sq(adj) = 0.00%


                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level       N    Mean   StDev  ---------+---------+---------+---------+
Zinc Green  3  0.5708  0.3798  (-----------------*-----------------)
Zinc Brown  3  0.5586  0.2862  (-----------------*-----------------)
                        ---------+---------+---------+---------+
                              0.30      0.60      0.90      1.20

Pooled StDev = 0.3363
```

RETRANSLOCATION

One-way ANOVA: Arsenic Gree, Cadmium Gree, Chromium Gre, Copper Green, ... Zona B

Source	DF	SS	MS	F	P
Factor	13	123.76	9.52	5.53	0.000
Error	28	48.20	1.72		
Total	41	171.96			

S = 1.312   R-Sq = 71.97%   R-Sq(adj) = 58.96%

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level            N   Mean  StDev  ------+---------+---------+---------+---
Arsenic Green    3  0.892  0.018     (------*-----)
Cadmium Green    3  0.446  0.009    (-----*-----)
Chromium Green   3  0.892  0.018     (------*-----)
Copper Green     3  1.205  0.276      (-----*-----)
Lead Green       3  0.446  0.009    (-----*-----)
Mercury Green    3  0.018  0.001  (-----*-----)
Zinc Green       3  5.327  3.828                    (-----*------)
Arsenic Brown    3  0.863  0.081     (-----*------)
Cadmium Brown    3  0.424  0.028   (------*-----)
Chromium Brown   3  0.848  0.056     (-----*------)
Copper Brown     3  0.988  0.211      (-----*-----)
Lead Brown       3  0.432  0.041    (-----*-----)
Mercury Brown    3  0.022  0.005  (-----*-----)
Zinc Brown       3  5.537  3.052                     (-----*-----)
                          ------+---------+---------+---------+---
                              0.0       2.5       5.0       7.5
```

Pooled StDev = 1.312

One-way ANOVA: Arsenic Gree, Cadmium Gree, Chromium Gre, Copper Green, ... Zona A

Source	DF	SS	MS	F	P
Factor	13	173.89	13.38	5.75	0.000
Error	28	65.12	2.33		
Total	41	239.00			

S = 1.525   R-Sq = 72.75%   R-Sq(adj) = 60.11%

```
                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level           N   Mean  StDev  ------+---------+---------+---------+---
Arsenic Green   3  0.845  0.028     (-----*-----)
Cadmium Green   3  0.423  0.014   (-----*-----)
Chromium Green  3  0.845  0.028     (-----*-----)
Copper Green    3  1.289  0.450      (-----*-----)
Lead Green      3  0.423  0.014   (-----*-----)
Mercury Green   3  0.017  0.000  (-----*-----)
Zinc Green      3  6.928  4.900                (-----*-----)
Arsenic Brown   3  0.879  0.028     (-----*-----)
Cadmium Brown   3  0.440  0.014   (-----*-----)
Chromium Brown  3  0.879  0.028     (-----*-----)
Copper Brown    3  1.694  1.285       (-----*-----)
Lead Brown      3  0.460  0.038   (-----*-----)
Mercury Brown   3  0.022  0.006  (-----*-----)
Zinc Brown      3  5.729  2.586               (-----*-----)
                              ------+---------+---------+---------+---
                                  0.0       3.0       6.0       9.0
```

Pooled StDev = 1.525

Bioaccumulation

One-way ANOVA: Arsenic Green, Arsenic Brown RED (ABC)

```
Source  DF       SS       MS     F      P
Factor   1  0.00010  0.00010  0.03  0.865
Error    4  0.01154  0.00289
Total    5  0.01164
```

S = 0.05372   R-Sq = 0.82%   R-Sq(adj) = 0.00%

```
                               Individual 95% CIs For Mean Based on
                               Pooled StDev
Level          N    Mean    StDev  --+---------+---------+---------+-------
Arsenic Green  3  0.23544  0.05711    (----------------*----------------)
Arsenic Brown  3  0.22748  0.05010  (----------------*-----------------)
                                   --+---------+---------+---------+-------
                                   0.150     0.200     0.250     0.300
```

Pooled StDev = 0.05372

One-way ANOVA: Cadmium Green, Cadmium Brown RED (ABC)

```
Source  DF   SS   MS     F      P
Factor   1    0    0  0.00  0.955
Error    4  410  103
Total    5  411

S = 10.13   R-Sq = 0.09%   R-Sq(adj) = 0.00%


                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level          N   Mean  StDev  ------+---------+---------+---------+---
Cadmium Green  3  10.26  10.37  (---------------*---------------)
Cadmium Brown  3   9.76   9.88  (---------------*---------------)
                              ------+---------+---------+---------+---
                                    0        10        20        30

Pooled StDev = 10.13
```

One-way ANOVA: Chromium Green, Chromium Brown RED (ABC)

```
Source  DF       SS       MS     F      P
Factor   1  0.00004  0.00004  0.02  0.908
Error    4  0.01147  0.00287
Total    5  0.01151

S = 0.05355   R-Sq = 0.38%   R-Sq(adj) = 0.00%


                                  Individual 95% CIs For Mean Based on
                                  Pooled StDev
Level           N     Mean    StDev  ----+---------+---------+---------+-----
Chromium Green  3  0.12189  0.05621   (----------------*-----------------)
Chromium Brown  3  0.11649  0.05075  (----------------*----------------)
                                  ----+---------+---------+---------+-----
                                    0.050     0.100     0.150     0.200

Pooled StDev = 0.05355
```

One-way ANOVA: Copper Green, Copper Brown RED (ABC)

```
Source  DF      SS      MS     F      P
Factor   1  0.0034  0.0034  0.30  0.615
Error    4  0.0464  0.0116
Total    5  0.0498

S = 0.1077   R-Sq = 6.92%   R-Sq(adj) = 0.00%


                             Individual 95% CIs For Mean Based on
                             Pooled StDev
Level         N    Mean   StDev  ------+---------+---------+---------+---
Copper Green  3  0.1608  0.1383       (----------------*----------------)
Copper Brown  3  0.1128  0.0637  (----------------*-----------------)
                             ------+---------+---------+---------+---
                                0.00      0.10      0.20      0.30

Pooled StDev = 0.1077
```

One-way ANOVA: Lead Green, Lead Brown RED (ABC)

```
Source  DF     SS     MS     F      P
Factor   1  0.000  0.000  0.00  0.959
Error    4  0.519  0.130
Total    5  0.519

S = 0.3601   R-Sq = 0.08%   R-Sq(adj) = 0.00%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level       N    Mean   StDev  --------+---------+---------+---------+-
Lead Green  3  0.3622  0.3691  (------------------*------------------)
Lead Brown  3  0.3459  0.3509  (-------------------*------------------)
                           --------+---------+---------+---------+-
                                0.00      0.30      0.60      0.90

Pooled StDev = 0.3601
```

One-way ANOVA: Mercury Green, Mercury Brown RED (ABC)

```
Source  DF    SS    MS     F      P
Factor   1  0.00  0.00  0.00  0.990
Error    4  6.23  1.56
Total    5  6.23

S = 1.248   R-Sq = 0.00%   R-Sq(adj) = 0.00%


                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level          N   Mean  StDev  ---+---------+---------+---------+------
Mercury Green  3  1.653  1.251  (-----------------*---------------)
Mercury Brown  3  1.667  1.244  (-----------------*-----------------)
                            ---+---------+---------+---------+------
                             0.0       1.2       2.4       3.6
Pooled StDev = 1.248
```

One-way ANOVA: Zinc Green, Zinc Brown RED (ABC)

Source	DF	SS	MS	F	P
Factor	1	0.00075	0.00075	0.14	0.727
Error	4	0.02127	0.00532		
Total	5	0.02202			

S = 0.07293   R-Sq = 3.40%   R-Sq(adj) = 0.00%

```
                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level       N    Mean    StDev  -----+---------+---------+---------+----
Zinc Green  3  0.15458  0.07369  (----------------*----------------)
Zinc Brown  3  0.17691  0.07215      (---------------*----------------)
                           -----+---------+---------+---------+----
                             0.070     0.140     0.210     0.280
```

Pooled StDev = 0.07293

One-way ANOVA: Arsenic Green, Arsenic Brow BLACK (ABC)

Source	DF	SS	MS	F	P
Factor	1	0.00140	0.00140	0.72	0.444
Error	4	0.00777	0.00194		
Total	5	0.00917			

S = 0.04407   R-Sq = 15.26%   R-Sq(adj) = 0.00%

```
                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level          N    Mean    StDev  -------+---------+---------+---------+--
Arsenic Green  3  0.23717  0.04958  (-------------*--------------)
Arsenic Brown  3  0.26770  0.03776       (--------------*-------------)
                              -------+---------+---------+---------+--
                                 0.200     0.250     0.300     0.350
```

Pooled StDev = 0.04407

One-way ANOVA: Cadmium Green, Cadmium Brown BLACK (ABC)

Source	DF	SS	MS	F	P
Factor	1	4	4	0.03	0.870
Error	4	587	147		
Total	5	591			

S = 12.11   R-Sq = 0.75%   R-Sq(adj) = 0.00%

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level          N   Mean  StDev  --------+---------+---------+---------+-
Cadmium Green  3  12.08  13.57    (---------------*---------------)
Cadmium Brown  3  10.37  10.45  (----------------*---------------)
                                --------+---------+---------+---------+-
                                        0        12        24        36
```

Pooled StDev = 12.11

One-way ANOVA: Chromium Green, Chromium Brown BLACK (ABC)

Source	DF	SS	MS	F	P
Factor	1	0.00000	0.00000	0.00	0.976
Error	4	0.01209	0.00302		
Total	5	0.01210			

S = 0.05498   R-Sq = 0.03%   R-Sq(adj) = 0.00%

```
                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level           N     Mean    StDev  ---+---------+---------+---------+------
Chromium Green  3  0.12226  0.05498  (----------------*-----------------)
Chromium Brown  3  0.12371  0.05499  (-----------------*----------------)
                                     ---+---------+---------+---------+------
                                      0.050     0.100     0.150     0.200
```

Pooled StDev = 0.05498

One-way ANOVA: Copper Green, Copper Brown BLACK (ABC)

```
Source  DF      SS      MS     F      P
Factor   1  0.0028  0.0028  0.13  0.735
Error    4  0.0856  0.0214
Total    5  0.0884

S = 0.1463   R-Sq = 3.20%   R-Sq(adj) = 0.00%


                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level         N    Mean   StDev  ---+---------+---------+---------+------
Copper Green  3  0.2372  0.1931     (---------------*--------------)
Copper Brown  3  0.1938  0.0741  (---------------*---------------)
                                 ---+---------+---------+---------+------
                                  0.00      0.15      0.30      0.45

Pooled StDev = 0.1463
```

One-way ANOVA: Lead Green, Lead Brown BLACK (ABC)

```
Source  DF     SS     MS     F      P
Factor   1  0.000  0.000  0.00  0.965
Error    4  0.559  0.140
Total    5  0.559

S = 0.3739   R-Sq = 0.05%   R-Sq(adj) = 0.00%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level       N    Mean   StDev  -------+---------+---------+---------+--
Lead Green  3  0.3655  0.3759  (----------------*-----------------)
Lead Brown  3  0.3796  0.3718   (----------------*-----------------)
                               -------+---------+---------+---------+--
                                   0.00      0.35      0.70      1.05

Pooled StDev = 0.3739
```

One-way ANOVA: Mercury Green, Mercury Brown BLACK (ABC)

Source	DF	SS	MS	F	P
Factor	1	1.03	1.03	0.47	0.531
Error	4	8.81	2.20		
Total	5	9.84			

S = 1.484   R-Sq = 10.51%   R-Sq(adj) = 0.00%

```
                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level          N   Mean  StDev  -----+---------+---------+---------+----
Mercury Green  3  1.624  1.124  (---------------*---------------)
Mercury Brown  3  2.455  1.772       (--------------*---------------)
                                -----+---------+---------+---------+----
                                   0.0       1.5       3.0       4.5
```

Pooled StDev = 1.484

One-way ANOVA: Zinc Green, Zinc Brown BLACK (ABC)

Source	DF	SS	MS	F	P
Factor	1	0.0218	0.0218	0.27	0.631
Error	4	0.3228	0.0807		
Total	5	0.3446			

S = 0.2841   R-Sq = 6.33%   R-Sq(adj) = 0.00%

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level       N    Mean   StDev  ------+---------+---------+---------+---
Zinc Green  3  0.6876  0.2928      (--------------*--------------)
Zinc Brown  3  0.5670  0.2751  (--------------*--------------)
                               ------+---------+---------+---------+---
                                   0.30      0.60      0.90      1.20
```

Pooled StDev = 0.2841

One-way ANOVA: Arsenic Green, Arsenic Brown WHITE ABC

```
Source  DF       SS       MS     F      P
Factor   1  0.00002  0.00002  0.01  0.943
Error    4  0.01327  0.00332
Total    5  0.01329

S = 0.05759   R-Sq = 0.14%   R-Sq(adj) = 0.00%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level          N     Mean    StDev  ---+---------+---------+---------+------
Arsenic Green  3  0.22557  0.06796  (-----------------*------------------)
Arsenic Brown  3  0.22913  0.04490  (------------------*-----------------)
                                    ---+---------+---------+---------+------
                                     0.150     0.200     0.250     0.300

Pooled StDev = 0.05759
```

One-way ANOVA: Cadmium Green, Cadmium Brown WHITE ABC

```
Source  DF   SS   MS     F      P
Factor   1    0    0  0.00  0.978
Error    4  409  102
Total    5  409

S = 10.11   R-Sq = 0.02%   R-Sq(adj) = 0.00%


                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level          N   Mean  StDev  ------+---------+---------+---------+---
Cadmium Green  3  10.06  10.10  (---------------*---------------)
Cadmium Brown  3   9.82  10.11  (---------------*---------------)
                                ------+---------+---------+---------+---
                                      0        10        20        30

Pooled StDev = 10.11
```

One-way ANOVA: Chromium Green, Chromium Brown WHITE ABC

```
Source  DF       SS       MS     F      P
Factor   1  0.00002  0.00002  0.01  0.943
Error    4  0.01083  0.00271
Total    5  0.01085

S = 0.05204   R-Sq = 0.15%   R-Sq(adj) = 0.00%


                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level           N     Mean    StDev  ---+---------+---------+---------+------
Chromium Green  3  0.12005  0.05416  (----------------*----------------)
Chromium Brown  3  0.11681  0.04983  (---------------*----------------)
                                 ---+---------+---------+---------+------
                                  0.050     0.100     0.150     0.200

Pooled StDev = 0.05204
```

One-way ANOVA: Copper Green, Copper Brown WHITE ABC

```
Source  DF       SS       MS     F      P
Factor   1  0.00278  0.00278  0.33  0.597
Error    4  0.03390  0.00848
Total    5  0.03669

S = 0.09207   R-Sq = 7.58%   R-Sq(adj) = 0.00%


                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level         N     Mean    StDev  ----+---------+---------+---------+-----
Copper Green  3  0.15001  0.10970      (--------------*--------------)
Copper Brown  3  0.10694  0.07013  (--------------*-------------)
                              ----+---------+---------+---------+-----
                                0.00      0.10      0.20      0.30

Pooled StDev = 0.09207
```

One-way ANOVA: Lead Green, Lead Brown WHITE ABC

Source	DF	SS	MS	F	P
Factor	1	0.012	0.012	0.06	0.814
Error	4	0.766	0.191		
Total	5	0.778			

S = 0.4375   R-Sq = 1.56%   R-Sq(adj) = 0.00%

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level        N    Mean   StDev  ---------+---------+---------+---------+
Lead Green   3  0.4395  0.5037   (-----------------*-----------------)
Lead Brown   3  0.3496  0.3593  (-----------------*----------------)
                          ---------+---------+---------+---------+
                               0.00      0.40      0.80      1.20
```

Pooled StDev = 0.4375

One-way ANOVA: Mercury Green, Mercury Brown WHITE ABC

Source	DF	SS	MS	F	P
Factor	1	0.03	0.03	0.02	0.903
Error	4	6.18	1.54		
Total	5	6.21			

S = 1.243   R-Sq = 0.42%   R-Sq(adj) = 0.00%

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level           N   Mean  StDev  ---+---------+---------+---------+------
Mercury Green   3  1.644  1.254  (----------------*---------------)
Mercury Brown   3  1.776  1.232   (----------------*---------------)
                          ---+---------+---------+---------+------
                           0.0       1.2       2.4       3.6
```

Pooled StDev = 1.243

One-way ANOVA: Zinc Green, Zinc Brown WHITE ABC

Source	DF	SS	MS	F	P
Factor	1	0.0059	0.0059	0.16	0.706
Error	4	0.1432	0.0358		
Total	5	0.1491			

S = 0.1892   R-Sq = 3.95%   R-Sq(adj) = 0.00%

```
                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level       N    Mean   StDev  --------+---------+---------+---------+-
Zinc Green  3  0.3354  0.1563  (--------------*--------------)
Zinc Brown  3  0.3981  0.2172     (--------------*--------------)
                               --------+---------+---------+---------+-
                                    0.20      0.40      0.60      0.80
```

Pooled StDev = 0.1892

APPENDIX 3

PICTURES OF FIELD VISITS TO PENINSULA LA ESPERANZA

La Malaria Creek, Cataño , Puerto Rico

Field Sampling at Peninsula La Esperanza