Insights into Local Sediment Radionuclide Absorption and Retention in the Island of Puerto Rico

Ithier-Guzmán, W. & Pyrtle, A. J., University of South Florida, College of Marine Science

Abstract: Anthropogenic radionuclides have been introduced to Puerto Rico, a United States (US) Commonwealth, via two major sources: global atmospheric fallout and local US government-sponsored tropical ecosystem experiments, prototype nuclear reactor testing and military artillery exercises. In October 2003 a preliminary investigation was initiated to examine the distribution and behavior of anthropogenic radionuclides in the Caribbean National Forest, Vieques and Rincon. During this investigation, sediment, vegetation and water samples were collected and analyzed. Analytical results of sediment samples indicate the presence of anthropogenic radionuclides at all three sample locations.

Surface and downcore Cs-137 distributions, as well as particle size characteristics of sediments collected from Vieques and Rincon are presented below. Results indicate that surface Cs-137 activities at the Vieques sampling sites range from below detection limits to 0.01 Bq/g. Particle concentrations vary at each location. The average concentration of clay size particles are slightly higher at Kianni Lagoon (6 % clay) than at Mosquito Bay (2 % clay). It is anticipated that outcomes from this on-going investigation will include an increased understanding of radionuclide concentrations, distributions and behaviors, with respect to local aquatic geochemistry, dominant transport processes and ecological characteristics.

Atmospheric Release of Anthropogenic Radionuclides

Anthropogenic (man-made) radionuclides were first released into the atmosphere in 1954. The atmospheric release of this artificially produced material has resulted in:

- Global atmospheric fallout, which has impacted natural resources worldwide
- Contamination of floodplains, waterways and coastal regions
- Contamination of lakes, lagoons, seas and open oceans
- Contamination of streams and rivers

Society Interest in Radionuclides

Results from past investigations of radionuclide behavior have been used to:

- Predict environmental impact of and determine effective remediation solutions for chemical accidents, chemical spills, etc.
- Determine the effects of human ingestion of and exposure to radionuclides via contaminated plants and animals.

Current Global Concern: What will happen if a nuclear reactor becomes a terrorist target?

Scientific Interest in Radionuclides

- Determine sediment burial and mixing rates
- Examine soil erosion
- Examine cation-clay mineral interaction
- Used to trace particle movement
- Used to date sediments and soils

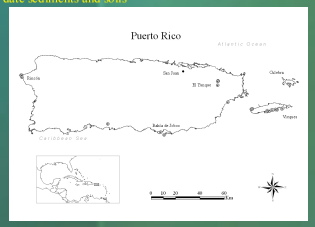


Figure 2. Map of the island of Puerto Rico showing the eastern island of Vieques

Background: Puerto Rico's Natural Resources

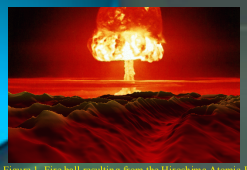
Puerto Rico, a United States (US) Commonwealth located in the Caribbean's Major Antilles, is comprised of several islands: a larger island, referred to as the main island and several smaller islands, of which only two (Vieques and Culebra) are inhabited. It's growing population of over four million people have created the need of major development projects (both residential and industrial) which has resulted in environmental:

- stress (e.g. viable drinking water limitations, increased erosion and sedimentation, decreased water quality, etc.)
- destruction (e.g. deforestation and habitat destruction) and
- anthropogenic contamination of the island's natural resources (Baqar et. al, 2003; Hunter and Arbona, 1995)

Most rivers and reservoirs in Puerto Rico have been adversely impacted by man (Hunter and Arbona, 1995). Even the groundwater shows evidence of contamination. In addition to environmental contamination by petrochemical facilities, landfills, and toxic dumps, **Puerto Rico's natural resources have also been exposed to anthropogenic radionuclides as a result of various US Department of Energy (US DOE) and Department of Defense (US DOD) sponsored activities (US DOE, 2003; US EPA, 2001; PRNC, 1970).** After entering Puerto Rico's groundwater these and other anthropogenic contaminants can be transported away from their introduction sites either as distinct insoluble subsurface plumes or within the groundwater itself to further impact the island's natural resources.

Figure 3a: Kianni Lagoon, Vieques

Figure 3b. Island of Vieques



http://www.emeagwali.com/interviews/national-society-of-black-engineers/national-conference-orlando-florida-2002/nuclear-explosion.gif

Figure 1. Fire ball resulting from the Hiroshima Atomic Bomb

Study Area and Sample Collection

Sediment cores from the island of Puerto Rico area aquatic system were obtained using a core liner. Sampling took place at:

Caribbean National Forest, "El Verde Experimental Station N18°19.351', W65°48.913'
Bonus Reactor, Rincon N18°21.969', W67°16.095'
Vieques N18°06.187', W65°27.074'

- Subsequently, the sediment cores were extruded and sectioned using a modified Glew (1988) extruder and transferred into "whirl pac" bags, weighed, frozen, freeze-dried
- Sediment samples were prepared for radionuclide analyses following Alexander et al. (1997).

Gamma Analysis

- Samples were assayed for gamma emitters using a Canberra Genie multichannel analyzer planar gamma detector.
  Calibration perform using US National Institute of Standards and Technology 4357 line and Ocean Sediment multi-line standards and the Canberra Multichannel MGS-5.
- Activities of the gamma emitters were determined via radionuclide-specific energy peaks located at 661 keV (Cs-137), average of 351.92^295.21 keV (Pb-214) and 46.5 (Pb-210).
- Excess Pb-210 was calculate by subtracting the Total [Pb-210] – [Pb-214]

Grain Size Analysis

An analysis of sediment particle size was also done using the Saturn Digisizer 5200 and particle sizes and population determinations were made. To estimate the population size one gram of the freeze dry sample was sieve using a #230 mesh (62 µm) screen sieve. After sieving the sample, the larger particles were retained via in a pre-weighed filter. The grain size distribution of the smaller particles were determined using standard methods for the Saturn Digisizer and Saturn Software 5200.

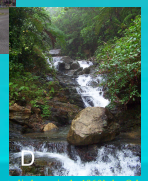


Figure 4 A.. Marine Environment at Rincón. B. El Verde Experimental Station, studied area in the 1960's by Odum C. Marine environment in Vieques, use for the past decades by the US Department of Defense for practicing purpose. D. Sonadora River Caribbean National Forest. E. Bonus Reactor, Rincon, built in the 1960's

Preliminary Results

Table 1. Sampling location, description of habitat conditions and surface Cs-137 activity. Errors associated with Cs-137 activities are ≤ ± 10 %

Sample	*Site Location*	*Type of Sample*	*Type of Environment*	*Water Depth (cm)*	*Cs-137(Bq/g)*
Green Bay	Vieques	Sediment	Marsh	10 cm	Below detection limits
S. Kianni Lagoon	Vieques	Sediment	Marsh	10 cm	Below detection limits
Baracuda Lagoon	Vieques	Soil	Lagoon	N/A	0.0107
Operational Posting Lagoon	Vieques	Soil	Lagoon	N/A	0.0006
S. Jobalos	Vieques	Sediment	Mangrove Forest and Lagoon	10 cm	0.0011
N. Jobalos	Vieques	Sediment	Mangrove Forest and Lagoon	10 cm	0.0214
El Verde Exp. Station	Caribbean National Forest	Soil	Tropical Forest	N/A	0.0734
El Verde Exp. Station	Caribbean National Forest	Soil	Tropical Forest	N/A	0.0172
El Verde Exp. Station	Caribbean National Forest	Soil	Tropical Forest	N/A	0.0518
El Verde Exp. Station	Caribbean National Forest	Soil	Tropical Forest	N/A	0.2887
El Verde Exp. Station	Caribbean National Forest	Soil	Tropical Forest	N/A	0.5631
El Verde Exp. Station	Caribbean National Forest	Soil	Tropical Forest	N/A	0.1399
El Verde Exp. Station	Caribbean National Forest	Soil	Tropical Forest	N/A	0.0400
El Verde Exp. Station	Caribbean National Forest	Soil	Tropical Forest	N/A	0.0978
South Bonus Beach	Rincon	Soil	Beach Area	N/A	0.0045
Beach at Bonus Area	Rincon	Soil	Beach Area	N/A	0.0116

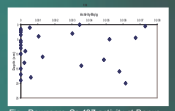


Fig. Downcore Cs-137 activity at Bonus Area Core 6, Rincón, PR. Errors associated with Cs-137 activities are ≤ ± 10 %.

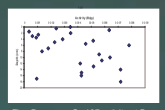


Fig. Downcore Cs-137 activity at Bonus Core 7, Rincón, PR. Errors associated with Cs-137 activities are ≤ ± 10 %.

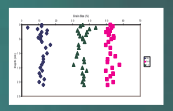


Fig. Grain size distribution at Bonus Area Core 6, Rincón, PR

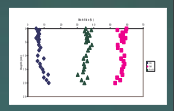


Fig. Grain size distribution at Bonus Area Core 7, Rincón, PR

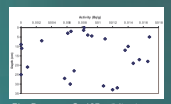


Fig. Downcore Cs-137 activity at Kianni Lagoon, Vieques, PR. Errors associated with Cs-137 activities are ≤ ± 10 %.

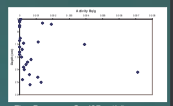


Fig. Downcore Cs-137 activity at Mosquito Bay, Vieques, PR. Errors associated with Cs-137 activities are ≤ ± 10 %.

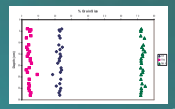


Fig. Grain size distribution at Kianni Lagoon, Vieques, PR

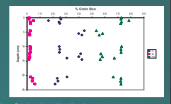


Fig. Grain size distribution at Mosquito Bay Lagoon, Vieques, PR

Preliminary Conclusions

- Sediment and soil samples indicate the presence of Cs-137 at each study site.
- Highest Cs-137 concentrations were identified at the Caribbean National Forest.
- Grain size results indicate clay size particle concentrations exceed 10 % at the Bonus Area, Rincon.
- Minimal clay content has likely influenced the retention of radionuclides at the various study sites.
- Further examination is needed to determine dominant factor(s) influencing the sediment retention capacity and stability at each location within Puerto Rico's ecosystem.

Acknowledgements:

We would like to acknowledge Mr. Jorge Ramos (Univ. Puerto Rico-Río Piedras), Dr. Joseph Smoak (Univ. of South Florida St. Petersburg), Dr. Frank Pyrtle III (Univ. of South Florida), Ms. Kemi Ogunsanwo (Univ. of South Florida), Ms. Marietta Mayo (Univ. of South Florida), Mr. Todd Robbins (Univ. of South Florida St. Petersburg), Ms. Aisha Johnson (Univ. of Houston), Ms. Asya Rence Purnell (Texas Southern Univ.), The Administration of Vieques National Wildlife Refuge and Oscar Diaz Refuge Manager, Dr. C. Benitez-Nelson (Univ. of South Carolina), Kanchan Maiti (Univ. of South Carolina), Professor Susanna Martinez (Inter-American Univ. San German), Raquel Hernandez (Florida Atlantic University).

This work was supported, in part, by the Univ. of South Florida Office of Research through the New Researchers Grant Program under Grant # R046908.

Selected Literature:

Aarkrog A. 2003. Input of anthropogenic radionuclides into the World Ocean. Deep-Sea Research II 50: 2597–2606
Glew J. (1991) Miniature gravity corer for recovering short sediment cores. *Journal of Paleolimnology*. **5**, 285-287.
Glew J. (1988) A portable extruding device for close interval sectioning of unconsolidated samples. *Journal of Paleolimnology*. 1, 235-239.
Hunter J. M. and S. I. Arbona. 1995. Paradise Lost: an introduction to the geography of water pollution in Puerto Rico. Soc. Sci. Med. Vol. 40, No. 10, pp. 1331-1355
Ithier-Guzman, W and Pyrtle, A.J. 2005. Sources and Fate of Anthropogenic Radionuclides in Puerto Rico: An Overview. Journal for Environmental Restoration. January 2005Johnson-Pyrtle A. and M. Scott. 2001. Distribution of Cs-137 in the Lena River Estuary-Laptev Sea System. *Marine Pollution Bulletin*. 42(10), p. 912-926
Myasoedov B. F. 2000. Century of radiochemistry: history and future. *Journal of Nuclear and Radiochemical Sciences*.1, 23-26
Puerto Rico Nuclear Center. 1970. The rainforest project, annual report, operated by the University of Puerto Rico under contract with the US Atomic Energy Commission