Pre-Final Report

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Title: Assessments of Well and Interstitial Water in Jobos Bay Natural Reserve and Agricultural Lands Close to Salinas Solid Waste Facility

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Focus Categories: TS, WQL, WL

Congressional District: (N/A)

Statement of Critical Water Problems:

Jobos Bay is located between Salinas and Guayama on the eastern south coast of Puerto Rico and comprises more than 2,500 acres, including the Aguirre Forest and a mangrove reserve, Jobos Bay National Research Reserve (JBNRR). The Salinas Fan Delta is the major aquifer in the Guayama, Salinas and Santa Isabel zone and is recharging the water in the JBNRR estuary (Gomez, 1990; Robles et al., 2003). The groundwater flow in the Salinas Quadrangle has been changing in the last twenty years because of variations in groundwater use causing significant changes in flow directions of groundwater (Robles et al., 2003). In fact, an extreme situation has caused a flow reversal (a depression cone), and now groundwater flows inland and southwest in some areas, thus increasing the risk of contamination from the Salinas Regional Waste Disposal Facility (SRWDF) in the JBNRR estuary.

SRWDF is a Regional Waste Disposal Facility in Salinas, very close to JBNRR. The site where SRWDF is located has five types of soils; thus layered/multiple hydraulic conductivities must be expected. SRWDF may affect JBNRR and adjacent agricultural and community lands; therefore it is necessary to assess the presence of toxic compounds. The surface water flow pattern on the west side of SRWDF is toward the southwest; from the east side, toward the southeast. Therefore, these waters may reach several estuarine zones in Salinas.

This project examined the soil and groundwater quality in the eastern part of JBNERR. The JBNERR is border by the east for Salinas Waste Disposal (SWD). Groundwater is the main source of fresh water in JBNERR. Some areas from JBNERR have been impacted by mangrove dieback associated with groundwater impairing. Therefore, groundwater quality is an important issue that must studied in order to have more knowledge of what is happening in JBNERR. Some JBNERR groundwater inflow lines appear passing very close to SWD and may impair JBNERR Ecosystem. This field and laboratory research helped to provide a more comprehensive view of the effect of SWD on water quality in the sampling zone. Besides it was complementary to other research studies related to inorganic contaminants in the zone.

Statements of the results or benefits:

Groundwater is the major source of fresh water for the Jobos Bay National Research Reserve (JBNERR). However, overuse of groundwater has induced marine water intrusion, which has caused black mangrove dieback in the JBNERR and may be affecting some croplands nearby. The JBNERR, the second largest mangrove forest of Puerto Rico, has been impaired with heavy metals and other toxic compounds. The major sources of heavy metals are mainly urban, such as paint wastes, deterioration of old pipes, battery disposal and dumping. Marine water intrusion has induced changes in the mobility of heavy metals, agrochemical and other toxic compounds in the groundwater. This study examined the groundwater quality and presence of agrochemical, heavy metals and other toxic substances in the Jobos Bay National Research Reserve and some agricultural lands nearby. In addition, it has shown that the entrance of marine water is impairing the environment in a dimension not taken into account until now, and may increase the risk of heavy metals and other toxic compounds entering the food chain in JBNERR.

Methodology:

Study Site

Water samples were collected between July 2004 and May 2005 from twenty-five piezometers (pipes with 3-mm holes to allow water entrance) distributed at five transects (Fig. 1). Piezometer depth ranged from five to fifteen feet.

Sample collection, preservation and handling

Triplicate water samples were collected in one-liter dark brown glass bottles with Teflon-lined caps (pre-washed with detergent and hot tap water, then rinsed with distilled and de-ionized water, and dried in an oven at 400° C for 1 h). The sampling was made by the use Teflon tubes of 1 cm coupled to a vacuum pump of 0.5 hp. All water samples were placed in an ice chest at around 4° C and transferred to the Central Analytical and Pesticide Laboratories at Río Piedras on the same day they were collected, and stored in a refrigerator at 4° C until extraction done the next day.

Dissolved trace metal and nutrient analysis

Standard AOAC method 974.27 was used for analysis of Pb, Cr and Mn by Atomic Absorption spectrophotometry (AA). Standard EPA method 365.1 was used for nutrients analysis.

Organic anthropogenic compound extraction and analysis

Organic compounds were extracted by the SPE-disk method as outlined by Mersie et al., 2002. A 1-L water sample was passed through a pre conditioned Empore C18 disk and re-extracted in 5 ml of ethyl acetate. Analyses were performed by gas chromatography/mass spectrometry (Perkin Elmer GC/MS Autosystem-TurboMass) by using a 30m x 0.25 mm x 0.10 m film thickness DB-5 capillary column with the following operating conditions: a temperature program of 3 min at 70° C, then increasing 10° C/min to 250° C and holding for 3 min; 3 min solvent delay on MS and helium carrier gas at 1.0 ml/min flow rate. An injection of 1µL in an injection port set in splitless mode at

250° C was used. The mass spectrometer detector was set at total ion mode, range 50 to 450 amu. Compound identification was based on the retention times and molecular fragmentation spectra identification by using a Wiley mass spectrum's library.

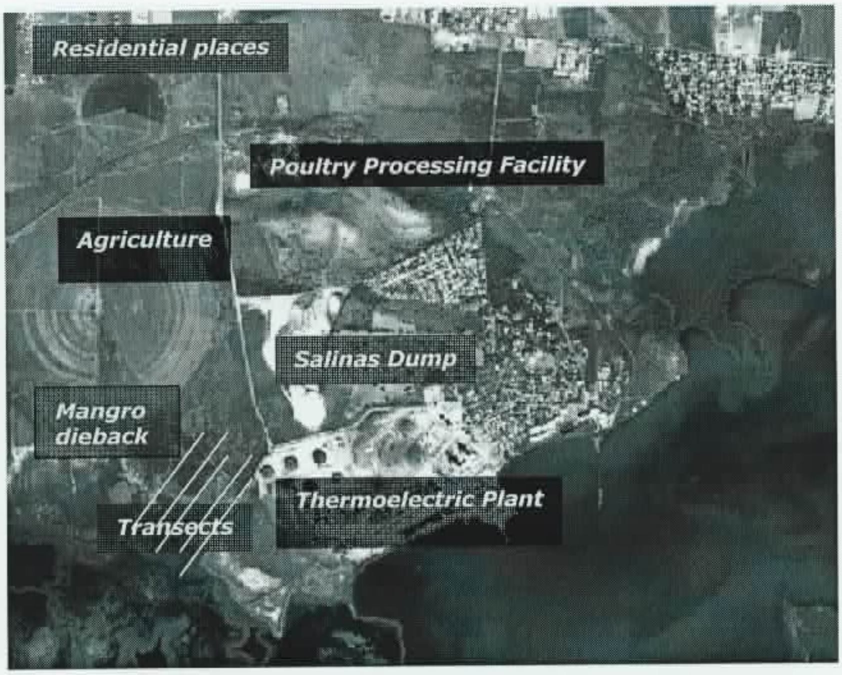

Figure 1. Map of the Jobos Bay region showing sampling transects – in the JBNERR and urban, industrial and agricultural activities surround.

Principal Findings and Significance:

Groundwater in the JBNERR study area had concentrations of lead that exceeded the National Recommended Water Quality Criteria (NRWQC) for freshwater and for salt water of 0.065 and 0.21 mg/L, respectively (Table 1). The mobility of contaminants over JBNERR ecosystem will depend on intrinsic parameters such as soil type and the surface and ground water flow patterns. The pH of groundwater in the study area of JBNERR was higher than 7.5, all of which promote hydroxyl lead complexes formation. Sorption of hydroxyl lead complexes to soil depends strongly on environmental ionic strength because main bonding force from hydroxyl lead complexes to soil under this condition must be electrostatic (Elzinga et al., 2002).

Table 1. Range of concentration of heavy metals in JBNERR groundwater sampling site from July 2004 to May 2005.

Metal	Range of concentration (mg/L)
Lead	ND-1.07
Manganese	ND-18.83
Chromium	ND-0.38

To determine how the marine water intrussion is affecting lead distribution on the study area, the concentration of lead was compared to salinity levels found in the groundwater samples taken from monitoring piezometers. We found lead concentration and salinity in JBNERR groundwater showed a pretty good lineal relationship (Figure 2).

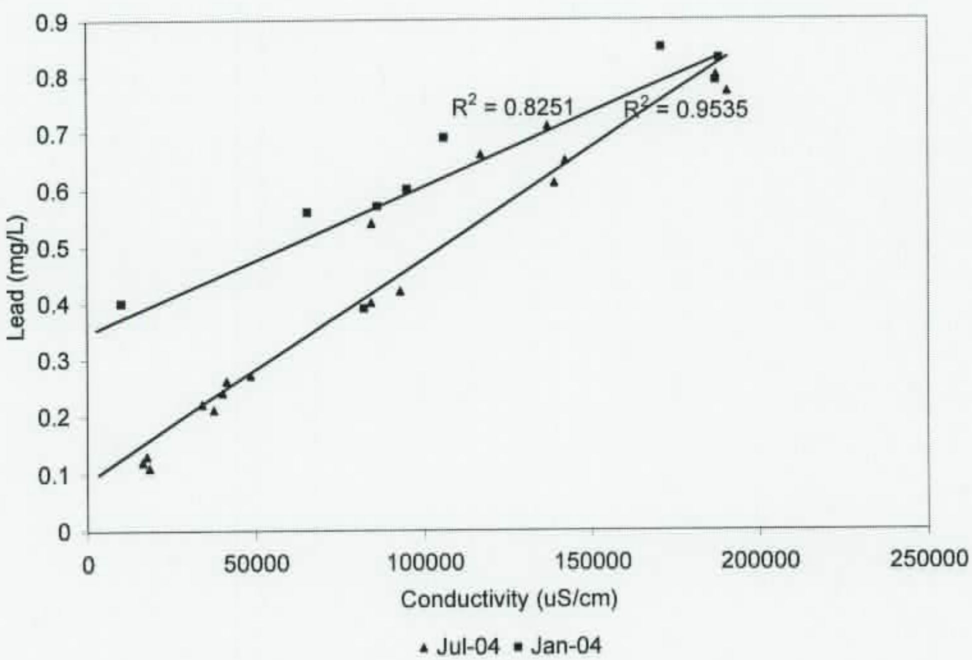

Figure 2. Linear lead vs. conductivity relationship in the JBNERR study site in two different times.

Lead behavior in the study site is explained because sodium present in the sea water can compete with lead sorption complexes for sorption sites. The high levels of lead suggest sources of incoming contamination that is affecting water quality of JBNERR. In addition, this trend of lead to increase concentration with salinity pinpoints that hydrologic changes in JBNERR, besides inducing black mangrove dieback, have changed lead sorption equilibrium in the study area.

Other heavy metals studied were water soluble chromium and manganese. Chromium concentration followed transects patterns which seem to be related to runoff from some point sources near the study area such as the SRWDF and the thermoelectric plant. However, further studies are needed to confirm this finding (Fig. 3).

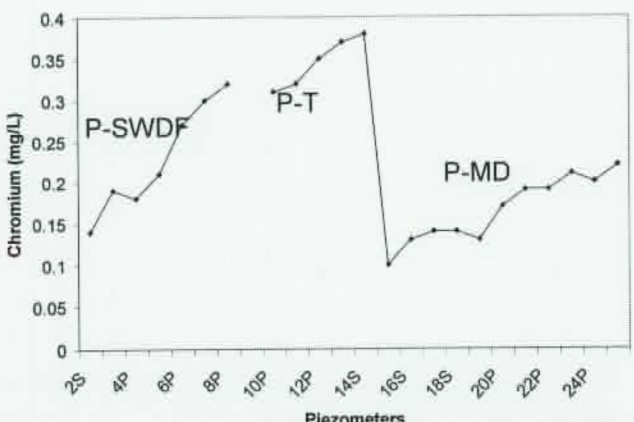

Figure 3. Chromium concentration in the study area (Sept-2004). P-SWDF=piezometers closest to SWDF; P-T=piezometers closest to the Thermoelectric plant; P-MD=piezometers closest to the mangrove dieback zone.

Manganese concentration showed no correlation with conductivity or sodium concentration; neither did it follow transected patterns as did chromium. Hot point areas of high concentration of manganese in groundwater of JBNERR were found which was relatively constant over time (Figure 4). Figure 4 shows the behavior observed for manganese concentration over time but for better understanding only one month is represented.

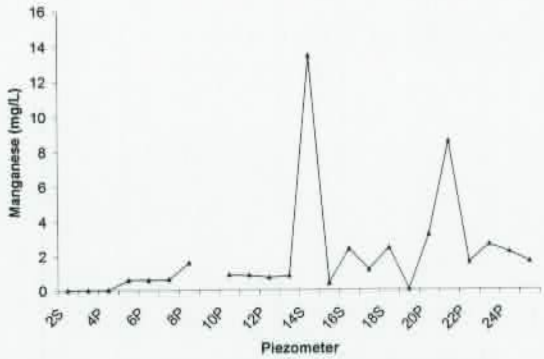

Figure 4. Manganese concentration in the study area (Sept-2004)

Higher phosphate concentration was found in groundwater samples taken from piezometers close to the black mangrove dieback area of JBNERR than other study areas. This finding may be explained since the mangrove dieback area of JBNERR is close to an abandoned sorghum growing farm and phosphate probably came from fertilizer application to that land some time ago (Fig. 5).

In addition decomposition of mangrove trees and flooded soil of mangrove dieback area may enhance phosphate releasing into groundwater of this area. This increase in phosphate may be the result of high amounts of dissolved organic matter in the mangrove dieback area all of which cause water to become anoxic. Under water anoxic conditions the release of phosphate to soil solutions must be enhanced (Young et al., 2001). Another factor that has to be considered is that the mangrove dieback area showed the highest salinity in the study zone (Fig. 3). Therefore, the high concentration of phosphate in those JBNERR areas might also be related to the competition of phosphate between sediment and magnesium in seawater (Fig. 5).

Organic compounds, such as benzothiazole were identified in the JBNRR groundwater and might be an indicator of runoff from urban developments and dumps. Benzothiazole is an organic compound that has been associated with tire manufacturing, disposal and industrial wastewater (Evans et al., 2000). In addition, 1-methyl-2-pyrrolidinone, an industrial solvent, tert-butyl phenol and some plasticizers were widely found in the entire sampling zone. Statistical data about toxic organic compounds and their amount will be available as soon possible.

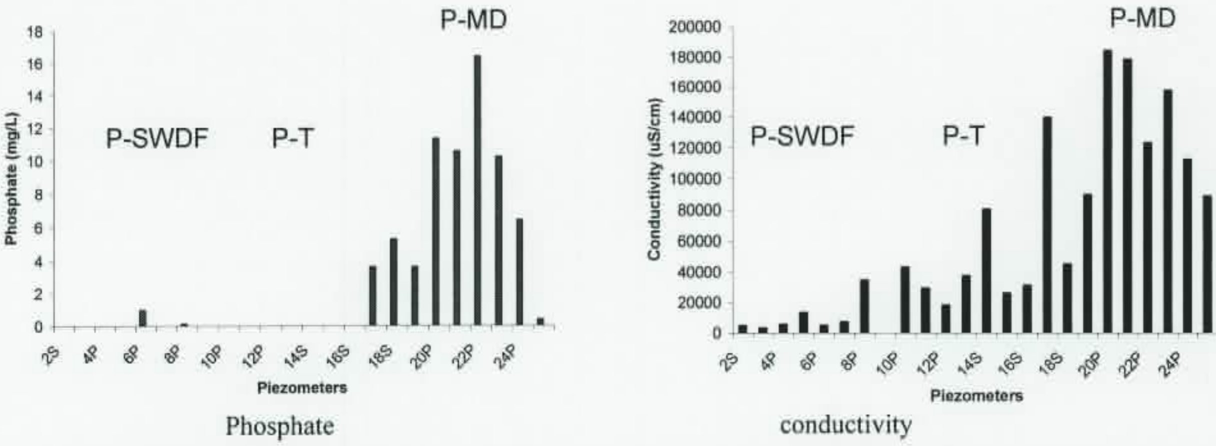

Figure 5. Phosphate concentration and conductivity in the study area (Sept-2004). P-SWDF=piezometers closest to SWDF; P-T=piezometers closest to the Thermoelectric plant; P-MD=piezometers closest to the mangrove dieback zone.

Heavy metals and anthropogenic organic compounds distribution in the JBNERR study area seems to be affected by hydrologic changes that are taking place in the zone. These hydrologic changes have been affecting the JBNERR ecosystem by promoting black mangrove dieback and also by changing metal species equilibrium, which may affect fish nurseries and some agricultural soils in the area. It is important to remark that organic toxic compounds were found but at very low levels and no pesticide related compounds from agricultural farms nearby were found.

References:

Gomez, F. and Quinones, V. 1990. Regional Aquifer systems of the United States: Aquifer of the caribbean islands. 1) Water resources development and its influence on the water budget for the Aquifer system in the Salinas to Patillas area, Puerto Rico. 2) Hydrochemistry of the south coastal plain aquifer system of Puerto Rico and its relation to surface water recharge.

Elzinga, E. J. and Sparks, D.L. 2002. X-ray absorption spectroscopy study of the effects of pH and ionic strength on Pb(II) sorption to amorphous silica. Environ. Sci. Technol. 36:4352-4357.

Evans, J.J., Shoemaker, C.A., Klesius, P.H. 2000. In vivo and in vitro effects of benzothiazole on sheepshead minnow (Cyprinodon Variegatus). Marine Environmental Research. 50:257-261.

Mersie, W.C., C. Clegg, R.D. Wauchope, J.A. Dumas, R.B. Leidy, M.B. Riley, R.W. Young, J.D. Mattice and T.C. Muller. 2002. Interlaboratory comparison of pesticide recovery from water using solid phase extraction disks and gas chromatography. Journal of AOAC International 85(6):1324-1330.

Robles, P.O., Gonzalez, C.M., Laboy, E.N. and Capella, J. 2003. Jobos Bay Estuarine Profile, A Nacional Estuarine Research Reserve. NOAA.

Young, E.O. and Ross, D.S. 2001. Phosphate release from seasonal flooded soils: A laboratory microcosm study. J. Environ. Qual. 30:91-101.

Related Presentations and publications:

Dumas, J. Montalvo, R. and Casanova, P. 2005. Saline effect in agrochemicals and heavy metals environmental distribution in Jobos Bay National Research Reserve. In: Proc., 41st Annual Meeting Caribbean. Food Crops Soc. In press.