



PROTECT

Puerto Rico Testsite for Exploring Contamination Threats



NIEHS

National Institute of
Environmental Health Sciences

Impacts of CVOCs and Phthalates Contamination in the Karst Groundwater System of Northern Puerto Rico

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Northeastern



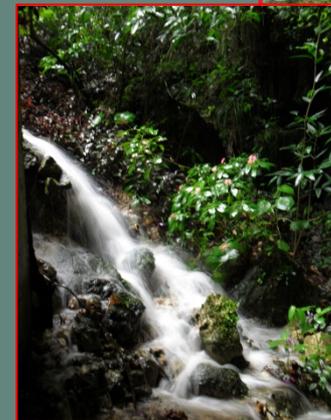
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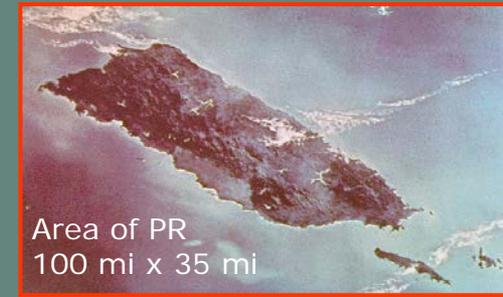
Outline

- Motivation and Background
 - North Coast Aquifer of PR
 - Public Health - PTB
- GW Contamination in northern PR
 - Extent
 - Impacts
- Concluding Remarks

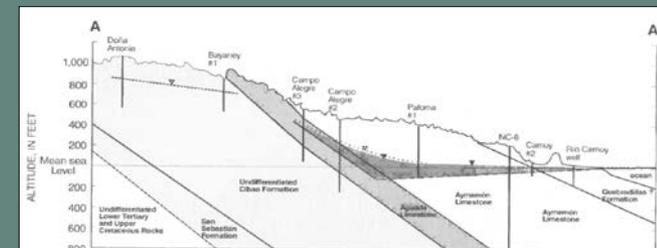
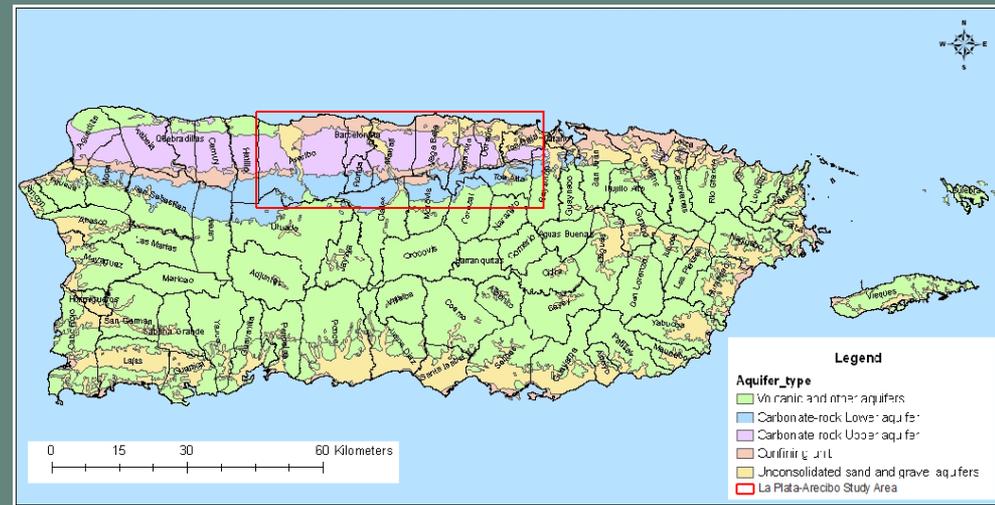




Karst Groundwater System of Northern Puerto Rico



- Karst areas cover over 19% of PR¹
- Primarily limestone with highly permeable karst aquifers
- “Shallow” Unconfined aquifer
- Deep confined aquifer



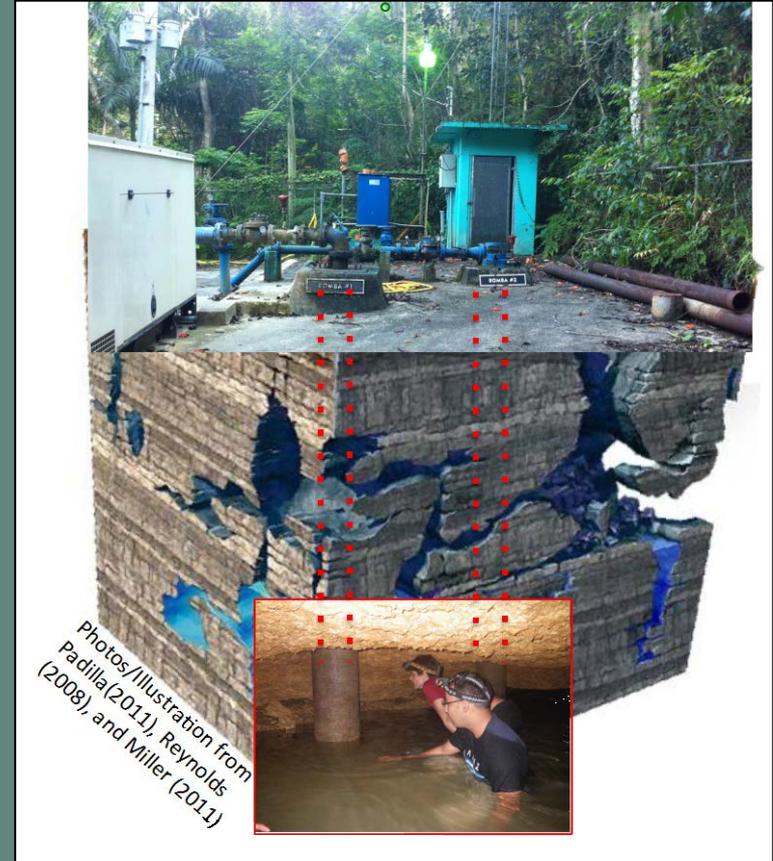
Torrez-Gonzalez, et al., 1996

¹Veve and Taggart, 1996



Karst Groundwater System of Northern Puerto Rico

- Characterized by conduit porosity and highly transmissive zones



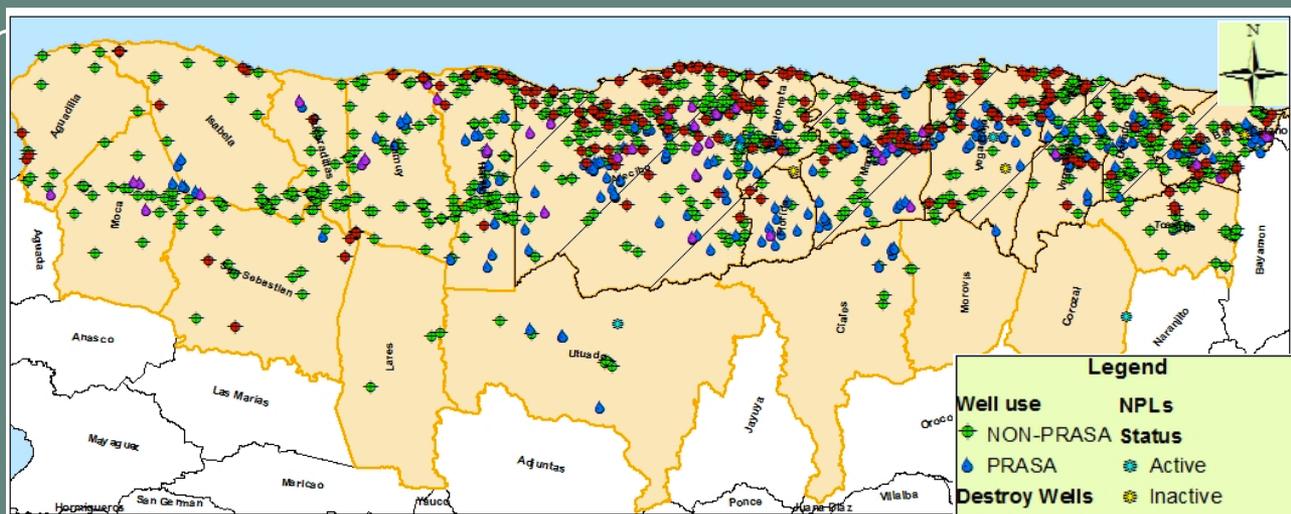
Monte Encantado Cave and Wells,
Moca, PR

Karst Groundwater System of Northern Puerto Rico



- Karst system is the most productive aquifer of the island¹
 - Provides over 52% of water supplied to the region²
 - domestic, industrial, and agricultural purposes, with the largest fraction

Water mostly extracted from the upper aquifer => most susceptible to contamination



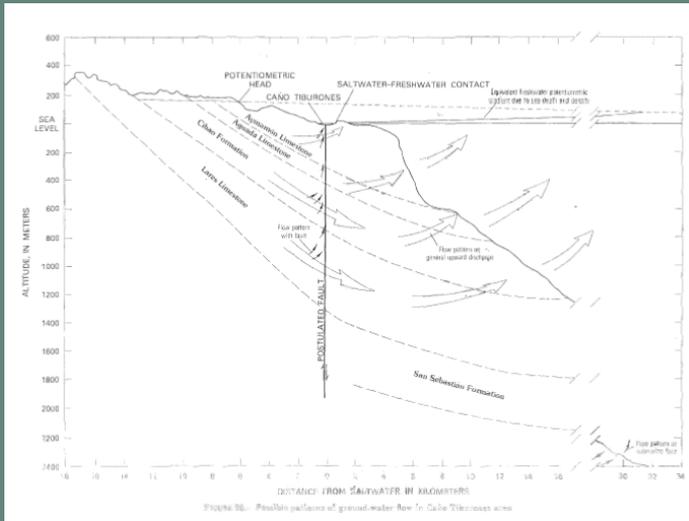
¹Veve and Taggart, 1996

²DNER, 2008

³Molina, 2009

Karst Groundwater System of Northern Puerto Rico

- Provides water resources for ecological integrity in the region



Guisti and Bennett, 1976



Karst Groundwater System of Northern Puerto Rico

- Contaminant transport characterized by a conduit- and diffuse-flow⁴



- Rapid transport to exposure sites
- Long-term storage of contamination



- Could serve as an important route of contaminant exposure

Contamination in the Karst Groundwater System of Northern Puerto Rico

- Over 40 years of contamination
 - 10 Superfund sites (and other potential ones)
 - Several unlined landfills above aquifer
 - 100s of other potential sources listed in TRI, CERCLA, RCRA
 - Industrial waste injections in confined aquifer before the 1970s

- Arecibo to Toa Baja hydrogeophysical area
 - ~285 mi²
 - 10 superfund sites
 - approximately 1 superfund site every 6 miles
 - TRIS = 44, RCRA = 249, CERCLA = 86



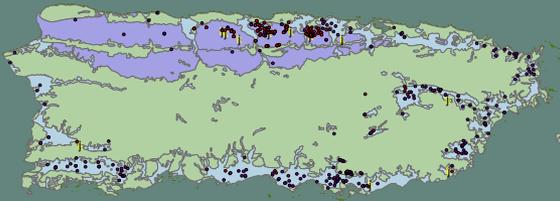
Superfund Sites and Landfills in Puerto Rico



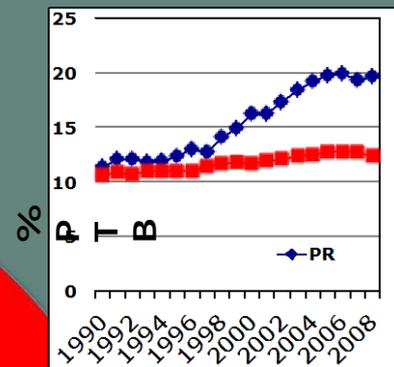
Contaminants of Interest

Contaminants

- Phthalates
- Chlorinated solvents (e.g., TCE)
- Mixtures

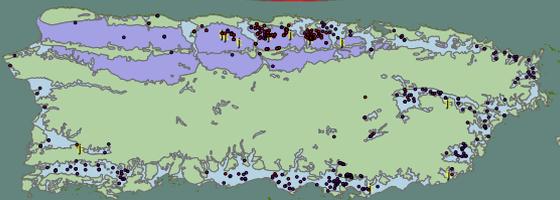


Public Health Motivation-PTB



Contaminants

- Phthalates
- Chlorinated solvents (e.g., TCE)
- Mixtures



Adverse Reproductive Outcomes¹

- Reproductive damage
- Decreased gestation length
- **Rise of preterm birth (PTB)**
- Lower birth weights
- Perinatal mortality
- Increased risk for spontaneous abortion



Higher Phthalate Metabolites Preterm Birth Cases vs. Controls

Geometric mean and median 3rd trimester urinary phthalate metabolite concentrations in women with term or preterm births.

Phthalate Metabolite	Geometric Mean		Median (25 th , 75 th percentile)		p-value ^a
	Term (n=30)	Preterm (n=30)	Term (n=30)	Preterm (n=30)	
MBP	38.1	89.9	33.4 (21.3, 74.0)	97.1 (56.0, 139)	0.005
MCPP	1.1	2.4	1.3 (0.5, 2.0)	2.3 (1.1, 4.9)	0.002
MBzP	2.3	5.2	2.9 (1.0, 5.2)	5.4 (2.6, 9.5)	0.01
MEP	112	204	108 (47.1, 224)	171 (69.4, 437)	0.1
MEHP	2.3	3.7	3.0 (0.6, 4.4)	4.3 (2.2, 7.1)	0.06
MEHHP	13.6	24.0	17.1 (6.2, 28.4)	28.7 (18.1, 37.5)	0.04
MEOHP	10.4	18.9	13.6 (5.0, 24.5)	20.8 (14.4, 25.5)	0.04
MECPP	29.7	51.2	38.2 (14.3, 53.8)	55.2 (39.2, 73.3)	0.02
Sum DEHP metab.	57.8	99.3	71.5 (26.8, 113)	112 (69.8, 135)	0.03

Meeker JD, Hu H, Cantonwine D, et al. Urinary phthalate metabolites in relation to preterm birth in Mexico City. *Environ Health Perspect*, 2009; 117:1587-2.



GW Contamination in Northern Puerto Rico

- Extensive historical (1982-2008) contamination of CVOCs and phthalates in both the shallow and deep-confined aquifers





Environmental Data

– Historical Contamination – 1983-2010

- Extensive historical contamination of CVOCs and phthalates in both, the shallow and deep-confined aquifers
- Contaminant distribution beyond the demarked sources of contamination
- Reflects a long-term potential exposure

GW Contamination in Northern Puerto Rico

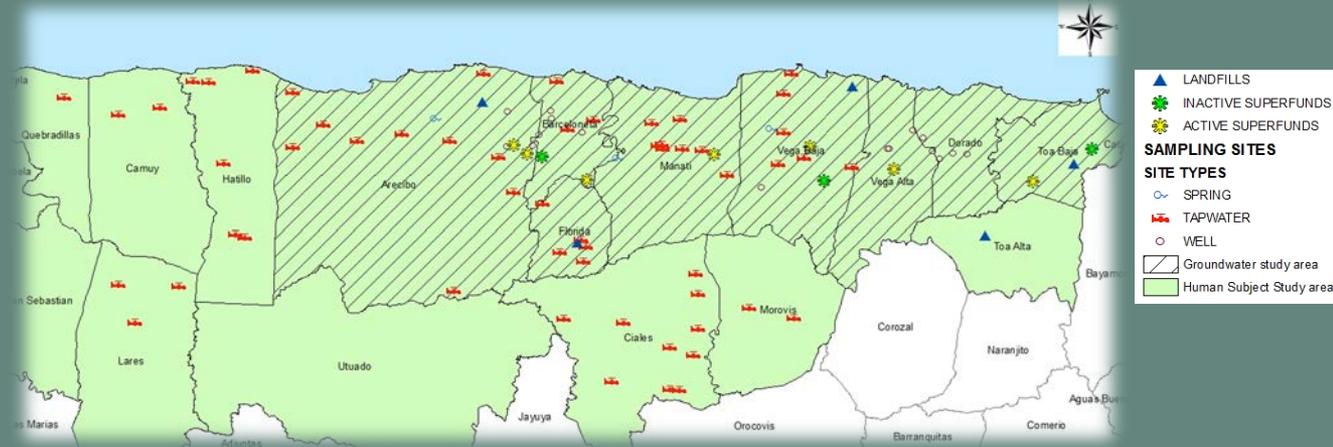


- Current sampling continues to detect CVOC and Phthalates

- 76% of wells sampled for **CVOCs** show detection
 - 47% mixtures

- 53% (dry season) and 100% (wet season) of wells sampled for **CVOCs** show detection
 - 18% mixtures (dry), 55% mixtures (wet)

- 12.5% of wells sampled for **phthalates** (DEHP, DBP) show detection in dry season
 - All related to mixtures with CVOCs



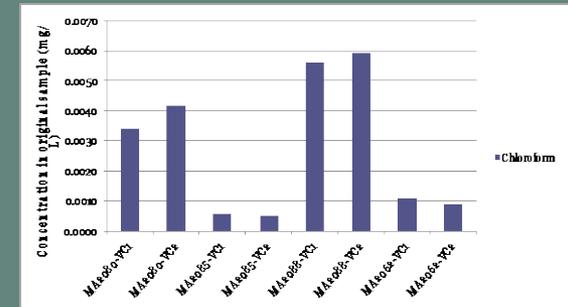
GW ID	Land Use	DRY SEASON (March 2011)		WET SEASON (October 2011)			
		PCE	TCE	PCE	TCE	1,1-DCE	Chloroform
1	Industrial	x	x	x	x		x
2	Agri			x	x		
3	Dom-PWS	x	x	x			
4	Dom-PWS	x	x	x	x		
5	Industrial			x	x	x	x
6	Agri						x
7	Agri			x			x
8	Agri						x
9	Agri		x		x		x
10	Spring		x				x
11	Spring		x			x	
12	Agri						
13	Dom		x				
14	Dom-PWS						
15	Agri/Dom						
16	Dom		x				
17	Spring						

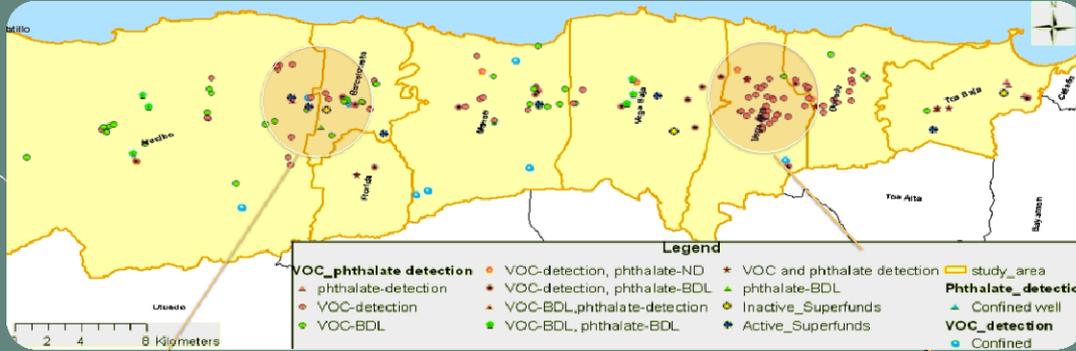
* Dom/PWS - domestic public water supply; Agri - agriculture, Dom-domestic water, ■ - not sampled, x-detected.



Environmental Data – Field Sampling–

- Tap water analysis
 - Chloroform (up to 30 ug/L)
 - Dibromochloromethane
- Phthalate contamination has been detected in many samples





ARECIBO	<p>MA2009</p> <p>Chloroform and PCE detected</p> <p>Pipe material: PVC</p>	<p>PozoPo</p> <p>Agricultural Use</p> <p>Chloroform and PCE detected</p> <p>Pipe material: PVC (excluding sampling port)</p>	Greatest Magnitude of Detections	<p>MA2085</p> <p>Only Chloroform detected at 0.005 mg/L</p>	<p>Pozo Ar</p> <p>Industrial Use</p> <p>Season I: No detection</p> <p>Season II: PCE, TCE, 1,1-DCE, & Chloroform</p>	VEGA BAJA

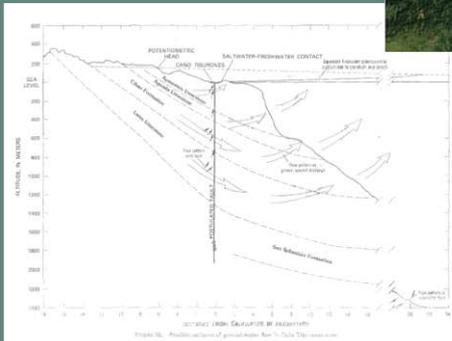
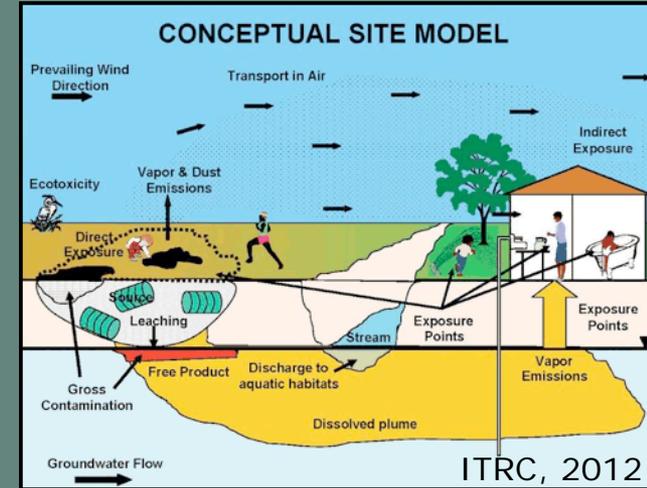
Sampling Locations for Groundwater Biannual Collection and Domestic Tap Water



Wet and Dry Season (March-April 2011 & October 2011, respectively) groundwater and human subjects sampling locations with Superfund Sites Only .

Contamination Impacts

- Increases potential exposure
 - Multiple mechanisms
 - Complex mixtures
 - Periodic





Contamination Impacts

- May affect public health
 - Preterm Birth
 - Major cause neonatal mortality
 - Increases incidence of health complications (Cordero, 2009)
 - Increases medical and health-associated cost (Time healthland, 2012)





Concluding Remarks

- Puerto Rico has had a long history of groundwater contamination
- In the northern karst aquifer of PR, contaminants are stored for a long time
- Large extent of groundwater contamination may be reaching water sources for human consumption and ecological integrity
- Exposure to contamination may impact public health and be associated with adverse reproductive outcomes (e.g., High PTB)
- GW Contamination reduces sources of water supply and increase cost of supplying water



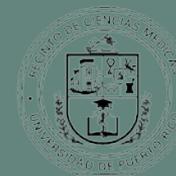
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