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PROTECT

Puerto Rico Testsite for Exploring Contamination Threats

Puerto Rico Testsite for Exploring Contamination Threats (PROTECT)

NIEHS SRP P42 Research Program

Northeastern University; University of Puerto Rico; University of Michigan

West Virginia University, Silent Spring Institute, EarthSoft

Directors: Akram N. Alshawabkeh & José F. Cordero

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Outline

- PROTECT Center Overview
- PROTECT Approach
- PROTECT Projects and Cores
- Acknowledgements


San Pedro Spring, PR

PROTECT Center

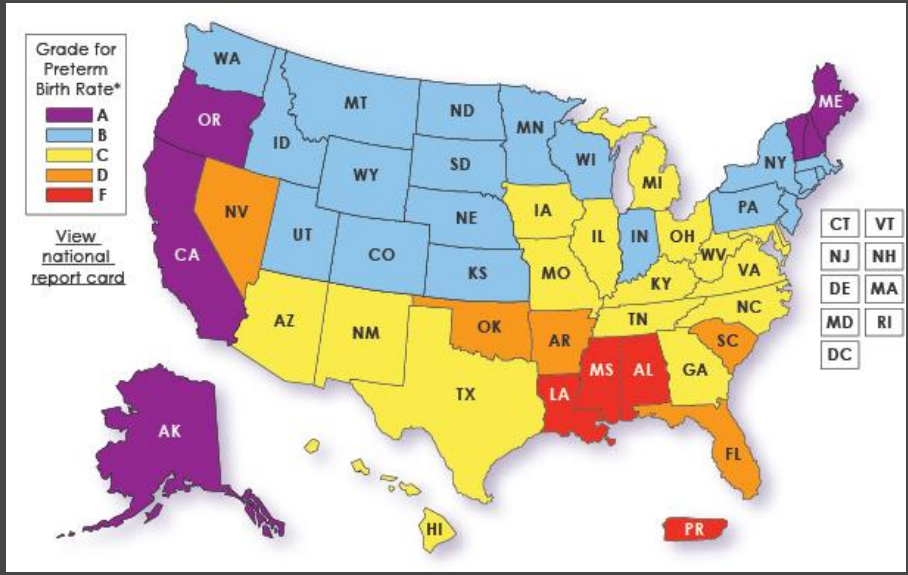
- Started in April 2010
- Involves many institutions and partners:
  - Northeastern University, University of Puerto Rico, University of Michigan, West Virginia University, Silent Spring Institute, EarthSoft Inc.
- Holistic source-to-outcome approach
- Diverse expertise
  - engineers, biochemists, electrochemists, toxicologists, epidemiologist, biostatisticians, pediatricians, agronomist, hydrogeologists, and social scientists.

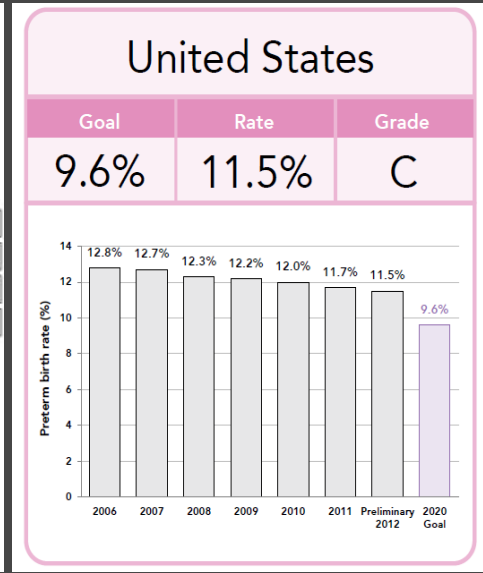
Key Aspects

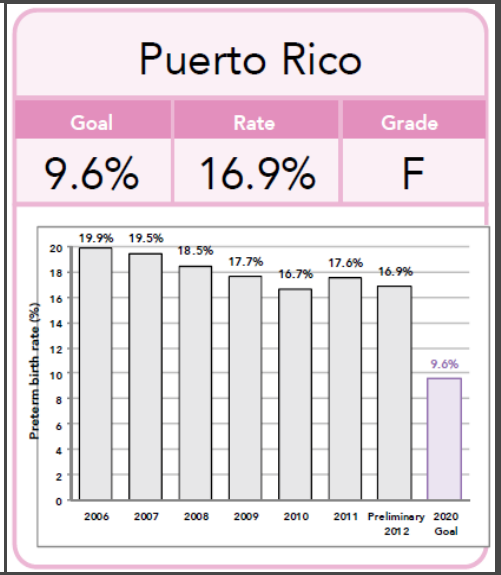
- Preterm Births
- Superfund Sites in Northern Puerto Rico
- Karst Hydrogeology
- Contamination focus
  - Chlorinated Solvents
  - Phthalates

Preterm Births, United States and Puerto Rico

March of Dimes 2013 Premature Birth Report Card







Babies born before 37 completed weeks of gestation are considered preterm.

Puerto Rico has the highest rate (17.7%) of any U.S. jurisdiction

Below only Malawi (18.1%) globally.

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Preterm Birth

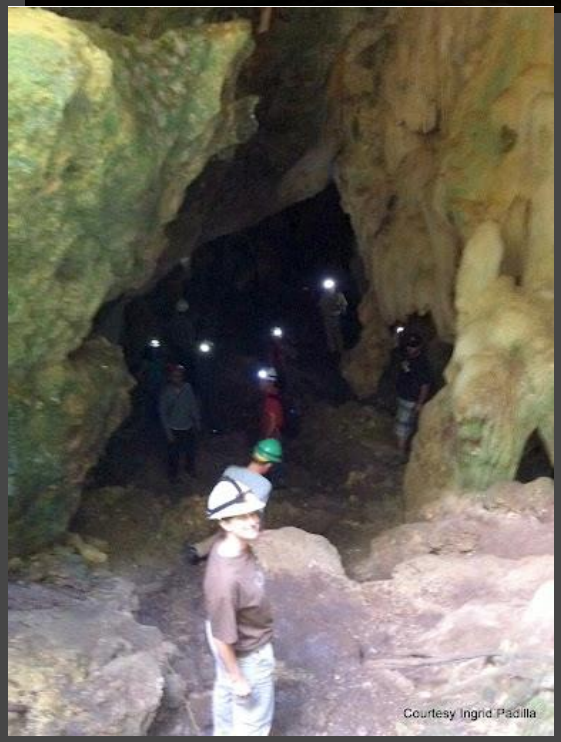
- Preterm birth (PTB) is the leading cause of neonatal mortality in the US, contributing to over one-third of infant deaths
- Results in high incidence of health complications that can lead to lifelong disabilities
- Preterm birth is a major, costly health problem in the US,

- Known risk factors for prematurity do not explain the marked increase in preterm births in the US and Puerto Rico

Contamination in Puerto Rico

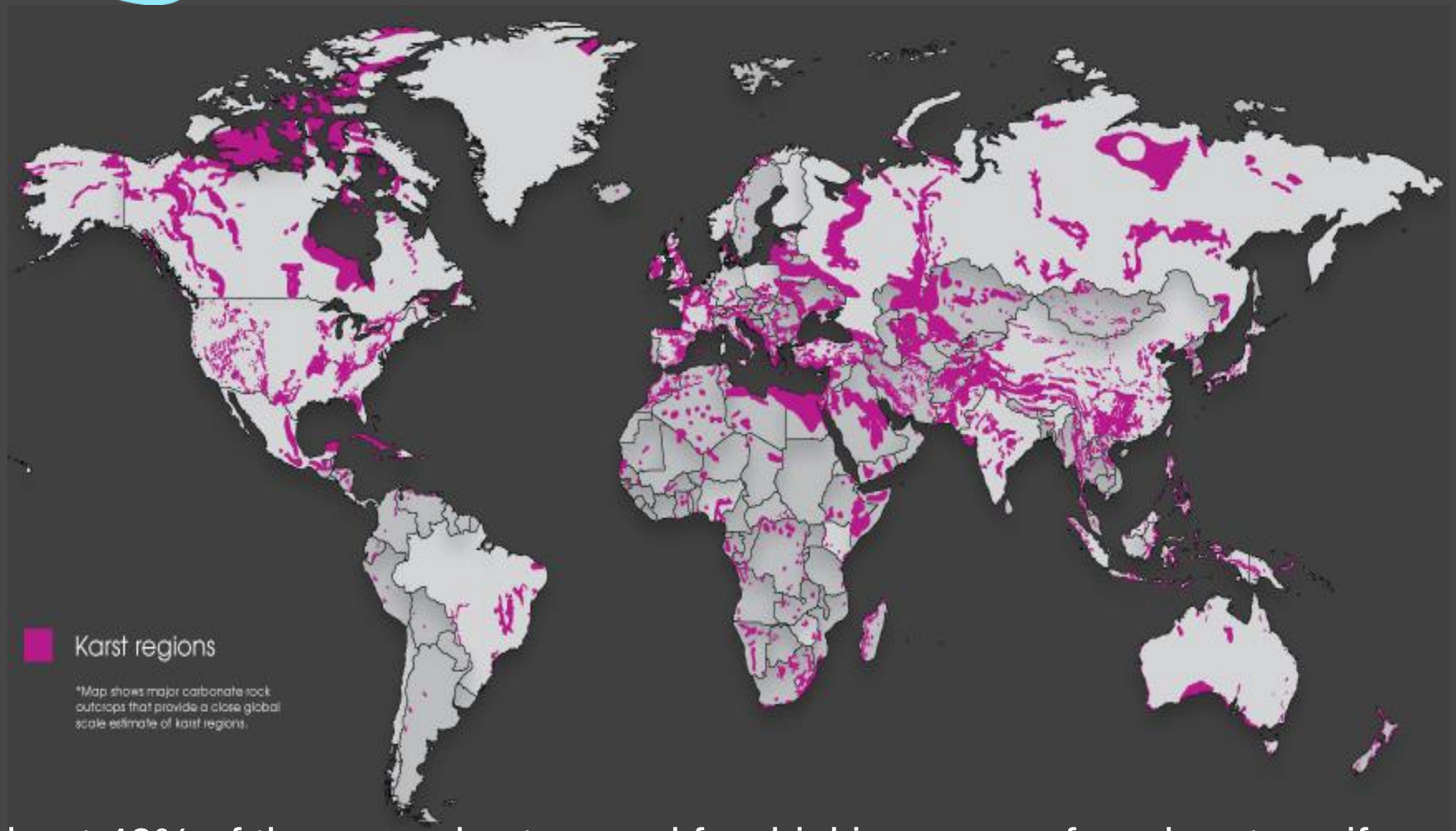
- 200+ Hazardous Waste Sites
- 16 Active Sites listed on the National Priority List (NPL); 22 Historical Sites
- Many sites include unlined landfills above aquifer in karst geologic formations
- Aquifer is primarily limestone with highly permeable karst aquifers from which most of the wells draw water

Karst



2012 Field Trip, PR

Karst



About 40% of the groundwater used for drinking comes from karst aquifers

Other parts of the world with large areas of karst include China and Europe

Research Questions

- What is the contribution of environmental contamination to preterm birth in PR?
- How significant is karst water as a route of exposure?
- Can we develop better strategies for detection and green remediation to minimize or prevent exposure to environmental contamination?

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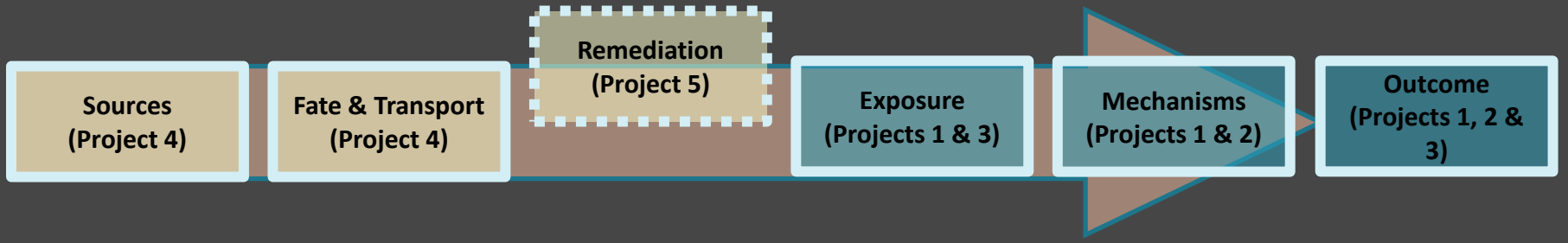
PROTECT Components

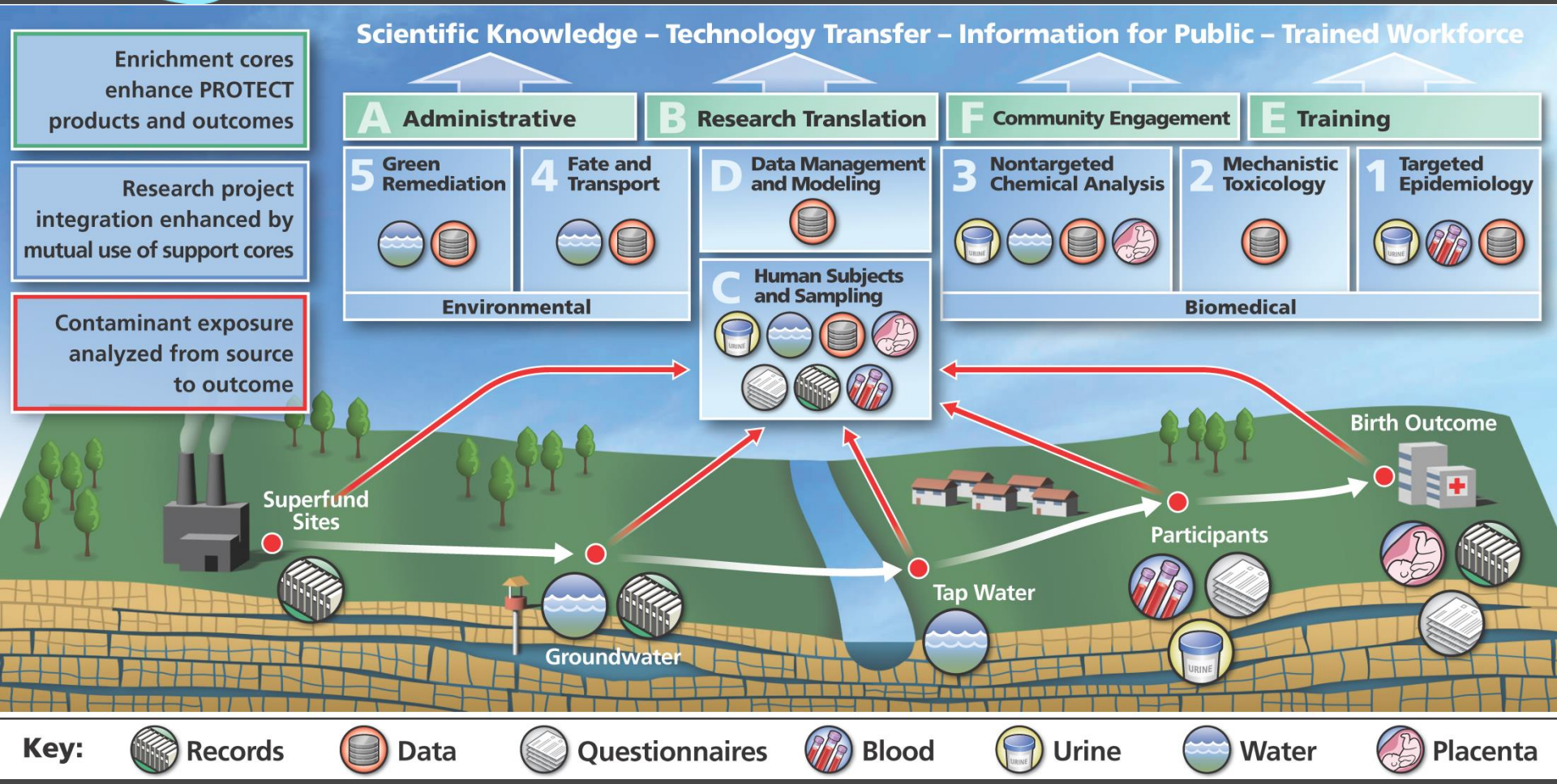
- 5 Projects
  - 3 Biomedical (Projects 1, 2 and 3)
  - 2 Environmental (Projects 4 and 5)
- 2 Research Support Cores
  - Human Subjects and Sampling Core
  - Data Management and Modeling Core
- 4 Enrichment Cores
  - Administrative Core
  - Research Translation Core
  - Training Core
  - Community Engagement Core

PROTECT Projects

- Project 1: Molecular epidemiology study
- Project 2: Mechanistic pathways study
- Project 3: Non-targeted analysis study
- Project 4: Fate and transport study
- Project 5: Remediation study



PROTECT Approach



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PROTECT Team


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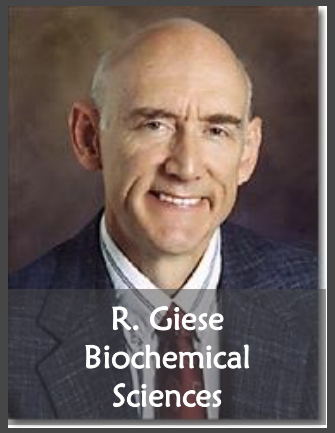
R. Giese
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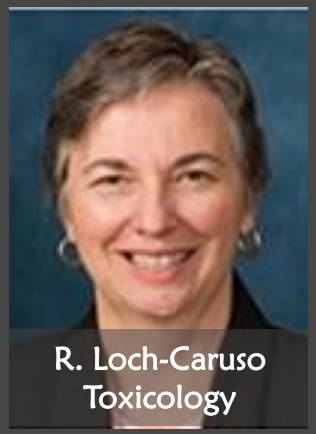
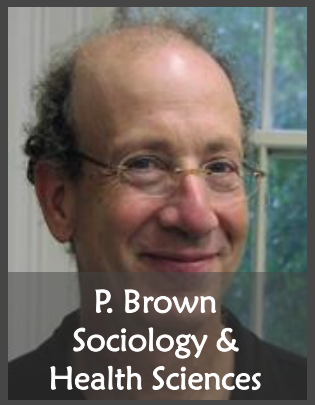

R. Loch-Caruso
Toxicology


J. Meeker
Epidemiology


P. Brown
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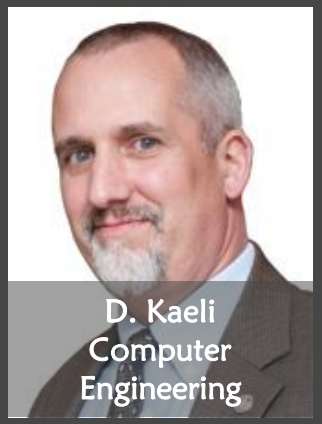
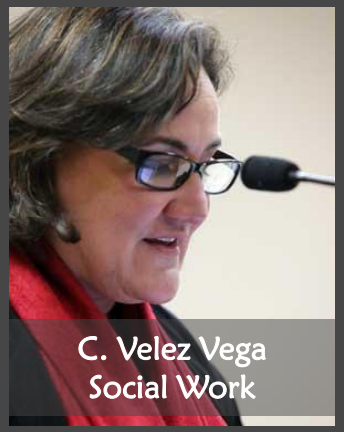
Health Sciences


D. Kaeli
Computer
Engineering


I. Padilla
Environmental
Engineering


C. Velez Vega
Social Work

Human Subjects Core and Biomedical Projects (1, 2 and 3)

Presented by José Cordero

Human Subjects and Sampling Core

Leader: José Cordero

- Maintain the infrastructure for recruitment and follow-up.
- Conduct sequential interviews, abstract medical records, and collect biological and environmental samples
- Process, archive, and distribute collected samples to project investigators;
- In collaboration with the Data Core, maintain a repository of samples with an integrated database.

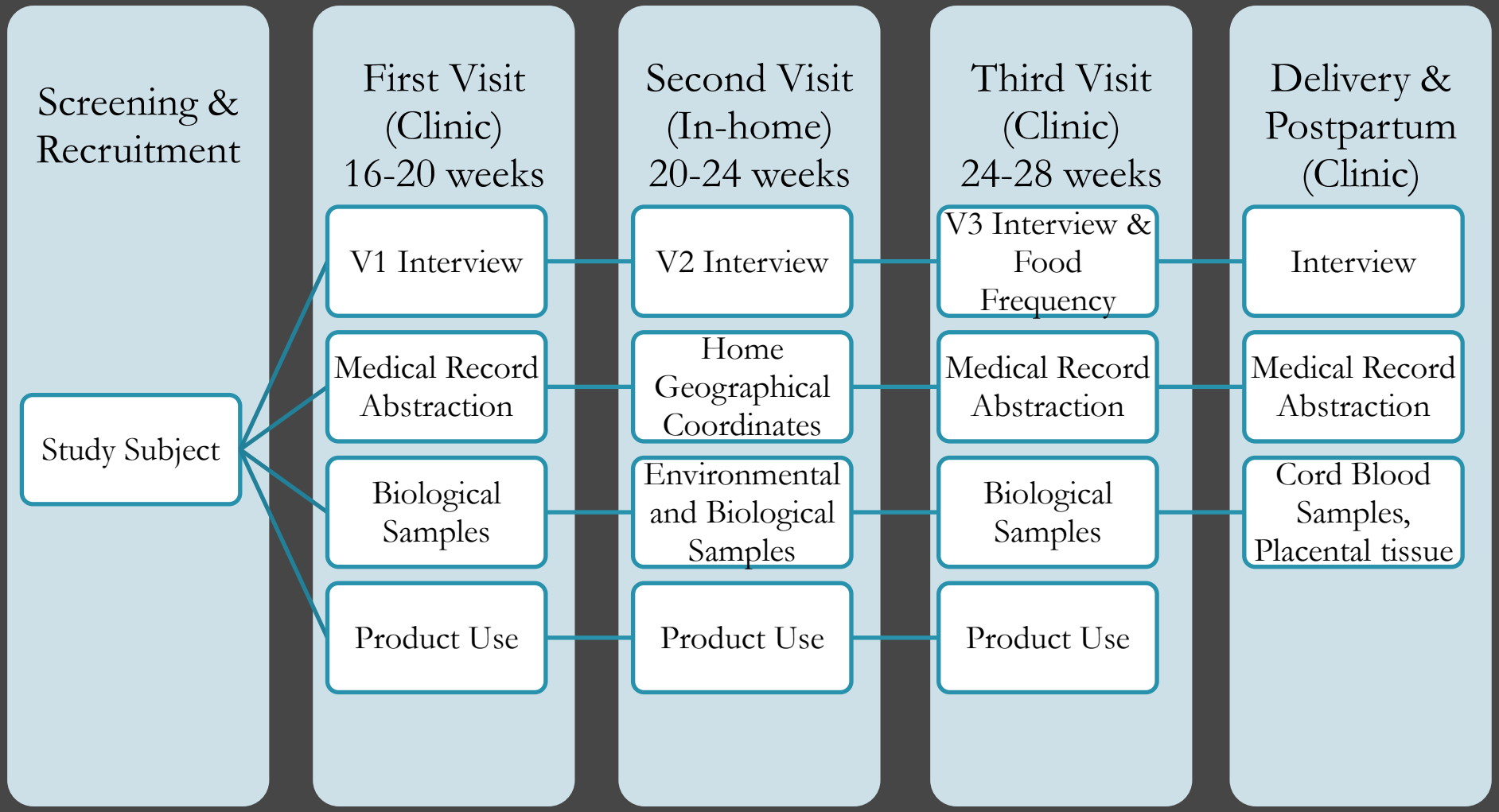
Study Area

Karst Region of Northern Puerto Rico

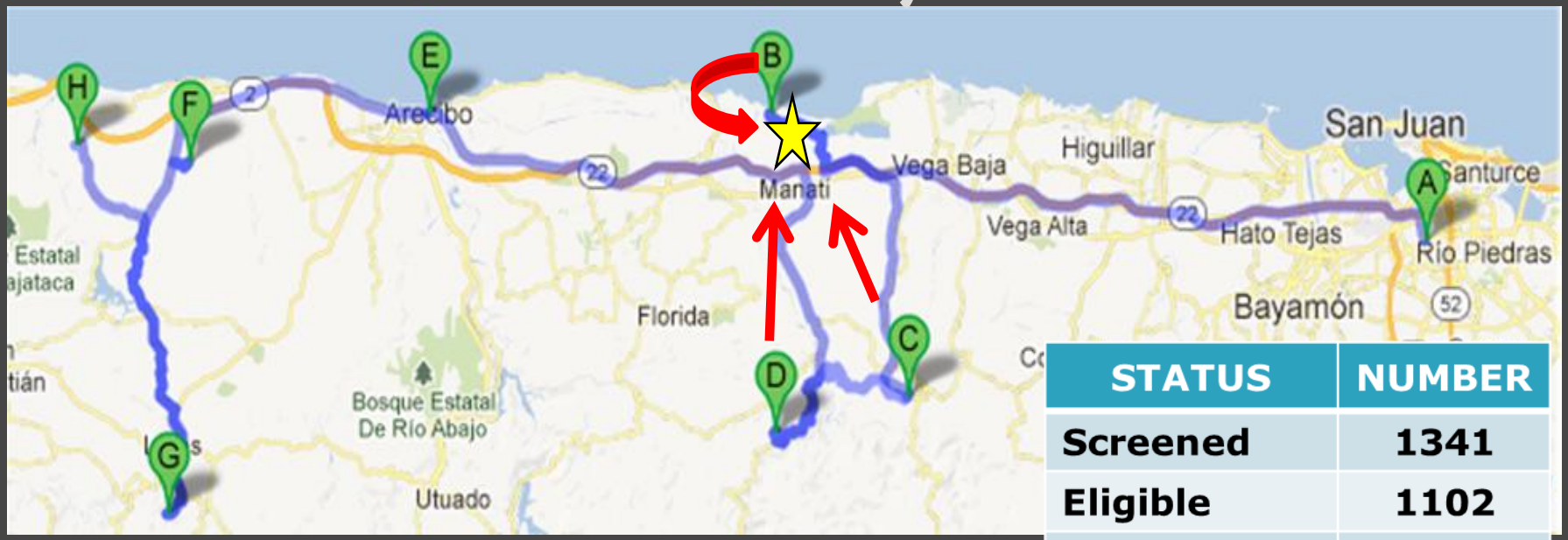
- Relatively large area (~1000 mi^2) with significant socioeconomical diversity

  => Requires strong community engagement component

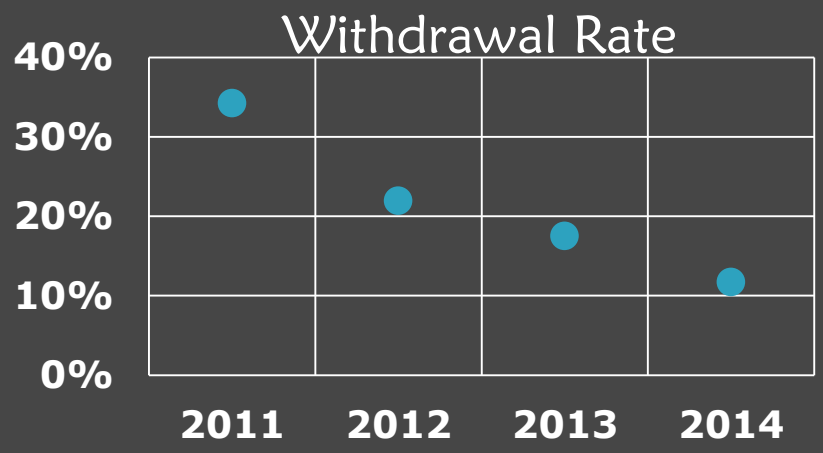
Participant Follow-up – Human Subjects Core -



PROTECT Recruitment As of July 2015



STATUS	NUMBER
Screened	1341
Eligible	1102
Recruited	951
Pregnancy completed	580
Live births	545
Other outcomes	38
Pregnancy in progress	190



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Project 1: Molecular Epidemiology Study of Phthalate Exposure and Preterm Birth in Puerto Rico

Leader: John Meeker; University of Michigan

- Investigate associations between exposure to phthalates during pregnancy and preterm birth.
- Identify connections between environmental chemicals and markers of inflammation, oxidative stress, and endocrine disruption.
- Determine factors associated with increased phthalate exposure to inform effective exposure and risk reduction efforts.

Project 1 Selected Results

- ✓ Urinary phthalate biomarkers can be detected in all women in the PROTECT cohort.
- ✓ Levels for certain phthalates are elevated in the PROTECT cohort compared to women of reproductive age in the United States (NHANES).
- ✓ Specific behaviors (use of perfume, makeup, and other personal care products) and conditions (drinking water source) may lead to elevated phthalate exposure levels and may represent points of intervention.
- ✓ Project 1 recently found strong and significant positive relationships between multiple phthalates in urine and markers of oxidative stress.

Project 1 Selected Results

- Drinking or cooking with water from private wells associated with higher DEHP metabolites, but not statistically significant (small N thus far).
- Increased MEP associated with: Use of perfume; Use of colored cosmetics and Use of nail polish.
- Increased MCNP or MCOP associated with:
  - *Plastic cistern for water storage*
  - *Microwaving food/drinks in plastic containers*
  - *Consumption of ice cream or chicken*

Table 2. Selected phthalate metabolites (ng/mL) in PROTECT compared to women 18-40 from NHANES.

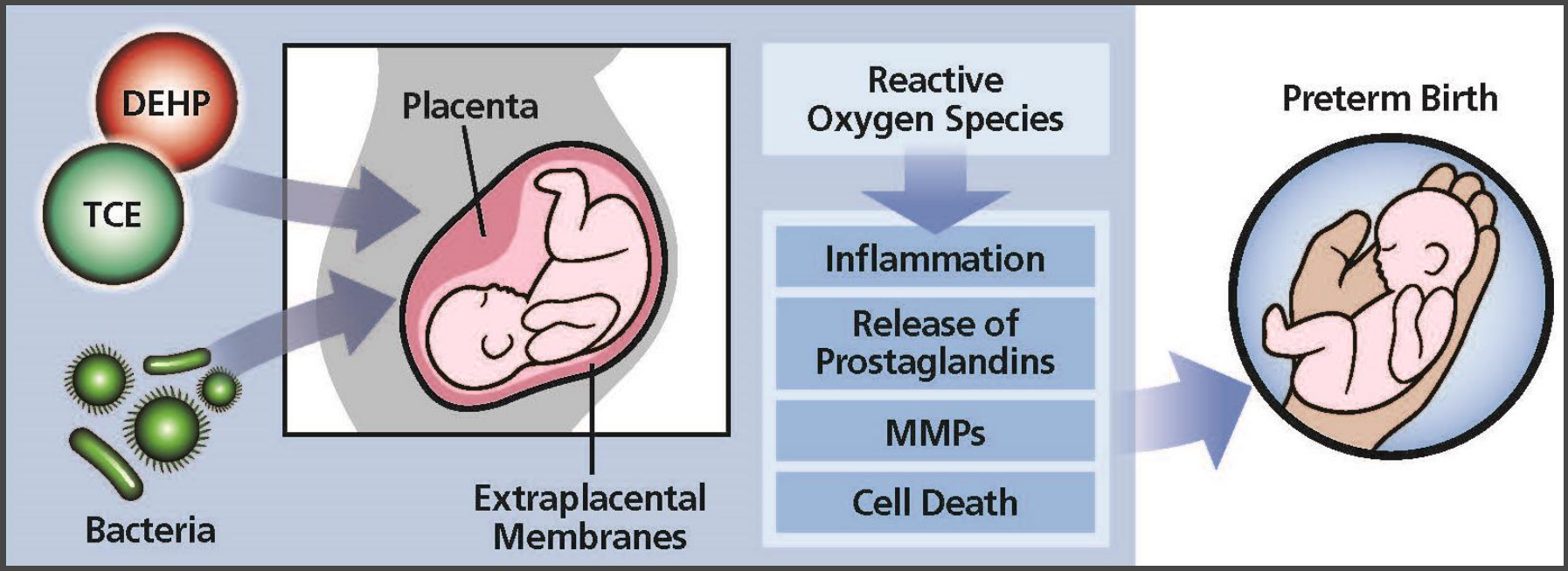
Analyte	Population	%>LOD	GeoMean	Percentiles		
				50th	75th	95th
MEHP	**PROTECT**	**92.9**	**3.3**	**3.7**	**7.4**	**17.5**
	NHANES	78.6	1.6	1.6	3.2	11.0
MECPP	**PROTECT**	**100**	**19.6**	**19.9**	**34.4**	**76.0**
	NHANES	100	17.9	17.5	32.3	95.3
MnBP	**PROTECT**	**98.7**	**19.2**	**20.9**	**42.0**	**117**
	NHANES	99.8	15.7	18.5	32.9	83.0
MiBP	**PROTECT**	**100**	**10.9**	**11.0**	**20.3**	**63.5**
	NHANES	99.8	8.8	9.6	18.6	42.0
MBzP	PROTECT	98.4	3.9	4.0	8.1	30.2
	NHANES	99.5	6.5	6.9	15.5	42.6
MCPP	PROTECT	98.9	2.3	2.2	4.1	20.7
	NHANES	96.4	2.7	2.8	6.0	23.4
MEP	**PROTECT**	**100**	**102.2**	**99.2**	**388**	**1880**
	NHANES	100	76.5	72.5	205	1286

Project 2: Toxicant Activation of Pathways of Preterm Birth in Gestational Tissues

Leader: Rita Loch-Caruso, University of Michigan

- Delineate the role of reactive oxygen species (ROS) in adverse pregnancy outcomes and tissue responses in rodents exposed to toxicants
- Develop and use *in vitro* models of human placenta and extraplacental membranes to identify mechanistic links between toxicant exposures and preterm birth
- Determine how immune cells contribute to toxicant-induced responses relevant to preterm birth
- Identify toxicant-induced modification of host defense against microbial infection of gestational tissues as a potential contributing factor to preterm birth

Project 2 - Mechanisms



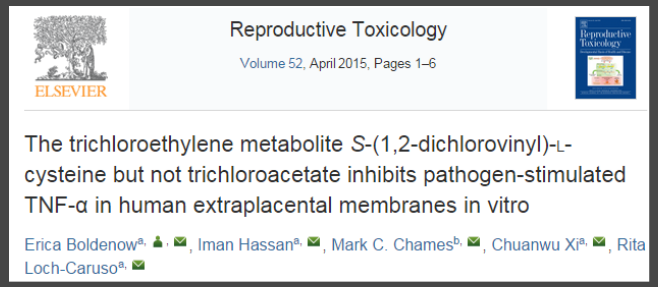
✓Diverse toxicants may contribute to preterm birth risk through an oxidative stress mechanism

Project 2 Selected Findings

- A phthalate metabolite (MEHP) stimulates ROS generation and prostaglandin expression in human placental cells (trophoblasts & macrophages) *in vitro*
- The trichloroethylene metabolite DCVC inhibits bacteria-stimulated host defense responses important for tissue resistance to microbial infection in human extraplacental membranes *in vitro*
- Pregnant rats exposed to TCE had litters with decreased fetal weight, placental oxidative DNA damage, and maternal inflammation

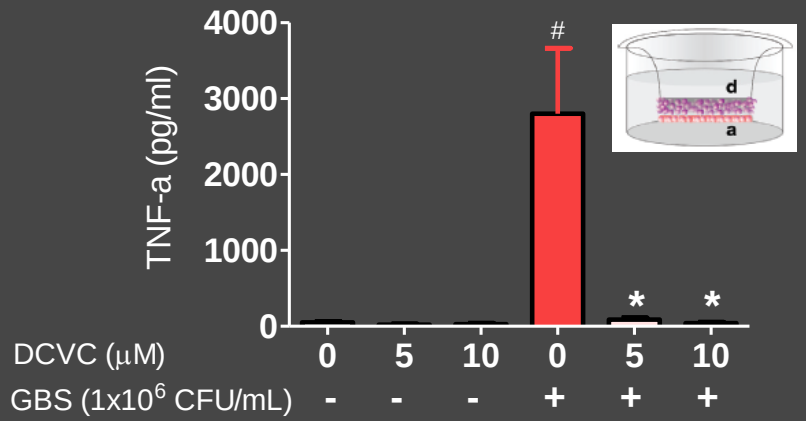
Project 2 Selected Results

- ✓ The TCE metabolite DCVC inhibits TNF-α production which is important for tissue defense against infection
- ✓ The phthalate metabolite MEHP stimulates freshly isolated human placental macrophages to increase production of prostaglandins, important activators of labor


Reproductive Toxicology
Volume 52, April 2015, Pages 1–6

The trichloroethylene metabolite *S*-(1,2-dichlorovinyl)-L-cysteine but not trichloroacetate inhibits pathogen-stimulated TNF-α in human extraplacental membranes in vitro

Erica Boldenow[a], Iman Hassan[a], Mark C. Chames[b], Chuanwu Xi[a], Rita Loch-Caruso[a]

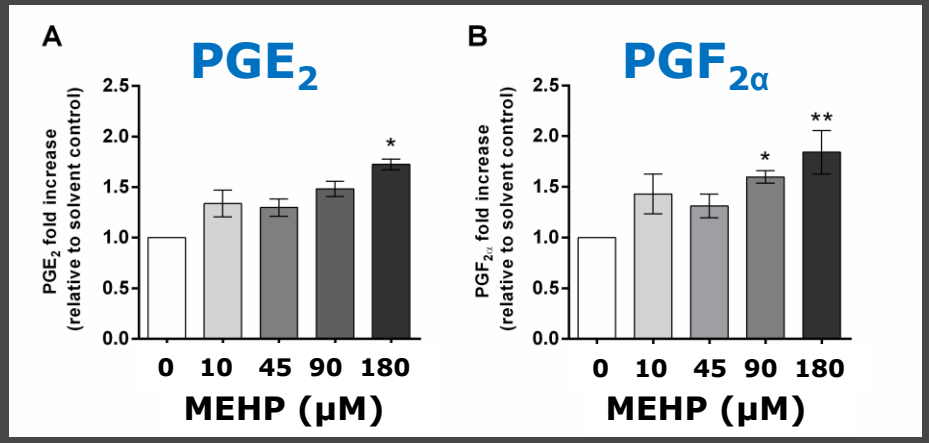


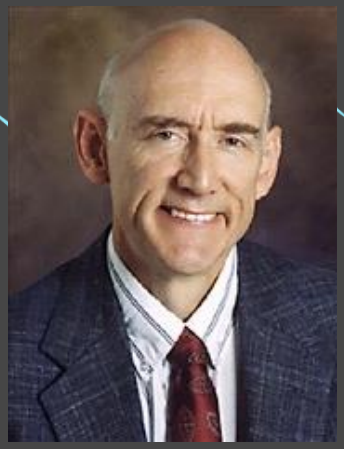
RB&E REPRODUCTIVE BIOLOGY AND ENDOCRINOLOGY

Mono-ethylhexyl phthalate stimulates prostaglandin secretion in human placental macrophages and THP-1 cells

Lauren M Tetz, David M Aronoff and Rita Loch-Caruso

Reproductive Biology and Endocrinology 2015, **13**:56 doi:10.1186/s12958-015-0046-8





Project 3: Discovery of Xenobiotics Associated with Preterm Birth

Leader: Dr. Roger Giese, Northeastern Univ.

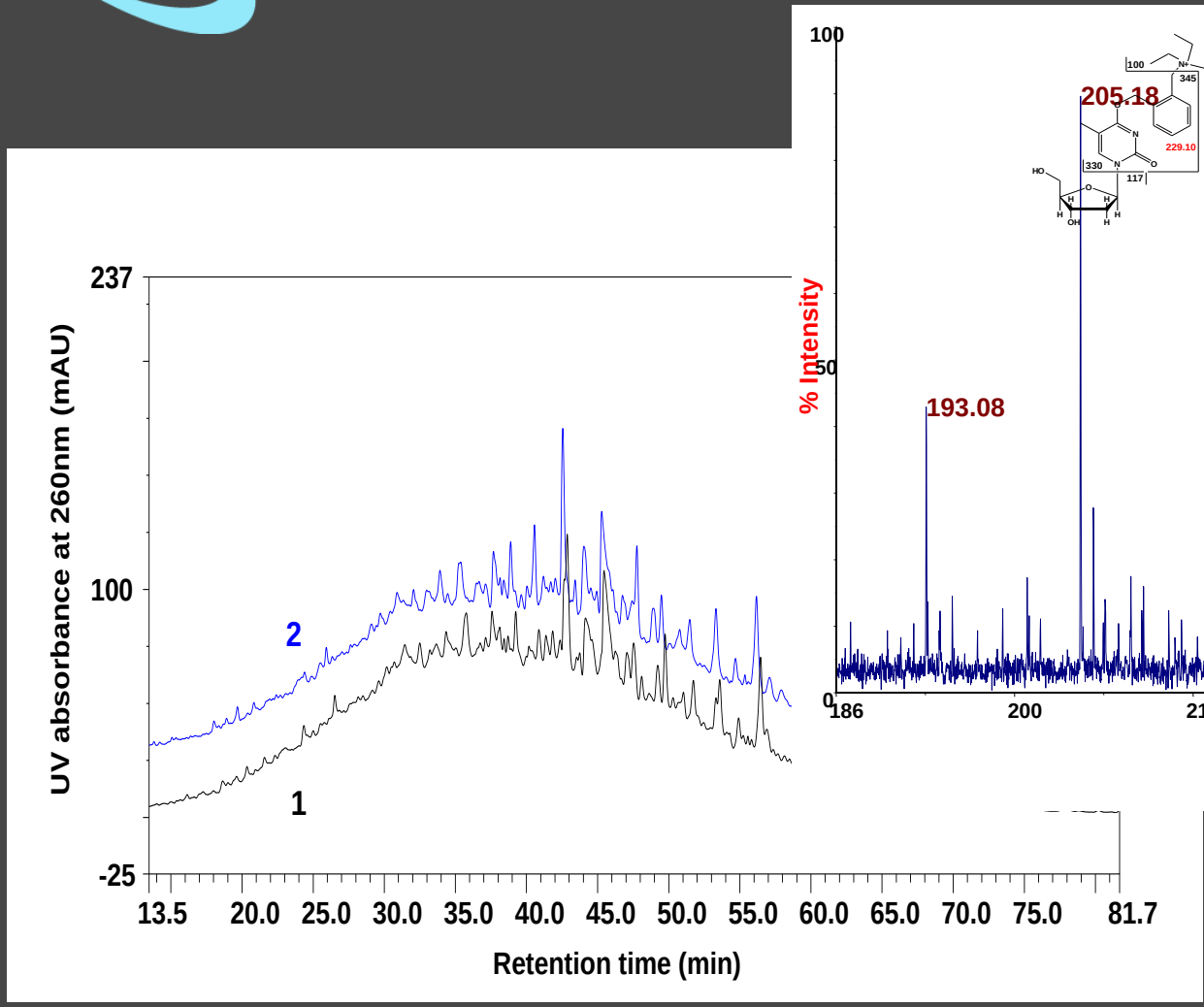
- Discover xenobiotics such as toxicant metabolites that contribute to preterm birth
- Explore xenobiotic profiles in the urine, placental tissues and water
- Compare patterns of DNA adducts in human placenta and laboratory-stressed placental cell cultures

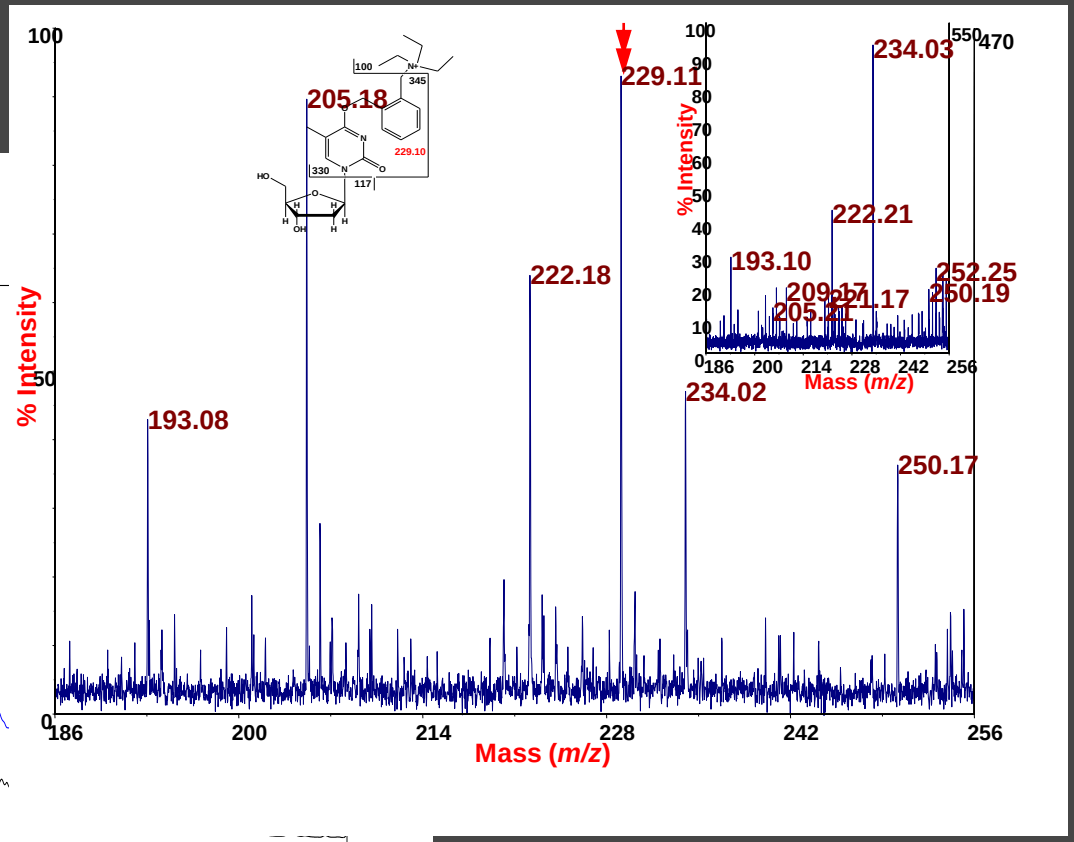
Porous Extraction Paddle (PEP)

Project 3 Selected Results

- ✓ Introduced PROTECT-developed xenobiotic detection technology called the Porous Extraction Paddle (PEP) for convenient extractions at remote sites – Patent application filed
- ✓ Developed CAX-B, a novel mass tag for ultrasensitive detection –Provisional patent application filed
- ✓ Increased detection of the urinary sulfateome by 75-fold (up to 1129 nonpolar sulfates)

Project 3 Selected Results





Detection of 160 amol of thymidine by CAX-Mass Spectrometry

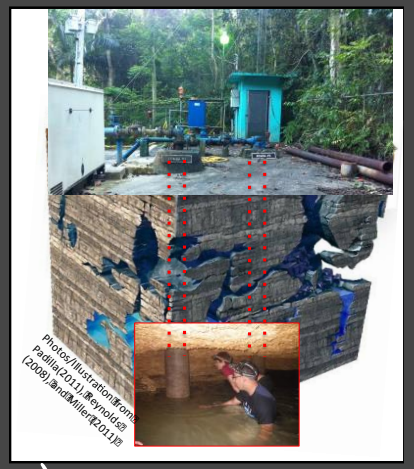
Two LC-UV chromatograms from 2 PEP extracts of urine 6 weeks apart: high reproducibility is seen.

Environmental Projects (3 and 4) and Data Management Core

Presented by Ingrid Padilla

Project 4: Dynamic Transport and Exposure Pathways of Contaminants in Karst Groundwater Systems

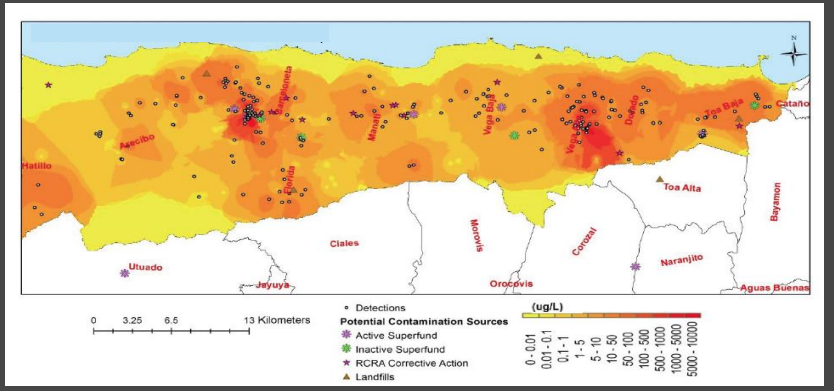
Leader: Ingrid Y. Padilla, Univ. of Puerto Rico, Mayagüez

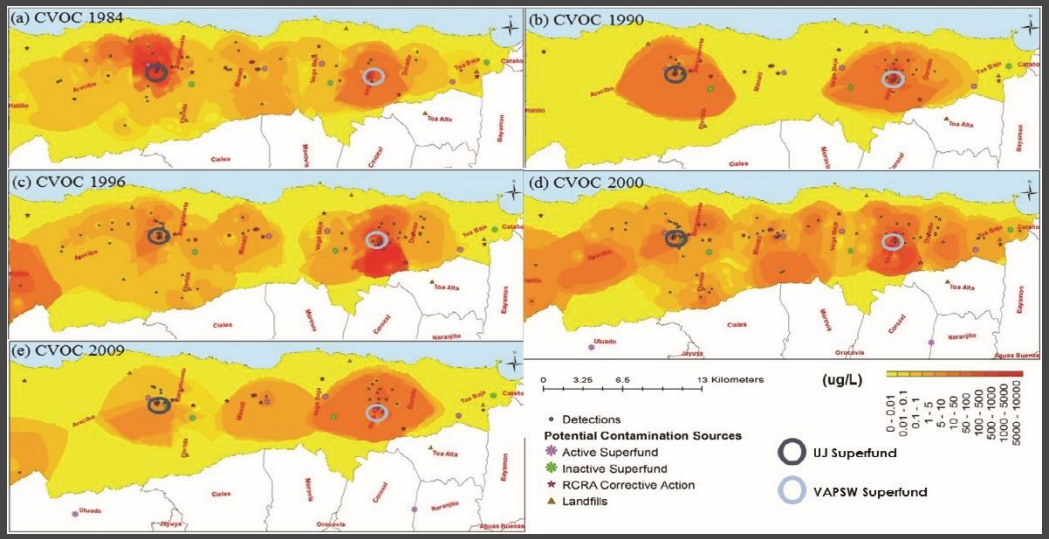


- Characterize fate and transport of contaminants in karst groundwater (conduit and diffusion dominated flow)
  - Fundamental Processes at Lab Scale
  - Applied Technologies at the Field Scale
- Assess spatial and temporal (historical and current) variability in water quality in groundwater and tap water
- Study contaminant distribution resulting from changes in contaminant sources, hydrologic conditions, remedial activities, and site management
- Develop new predictive tools to reduce exposure

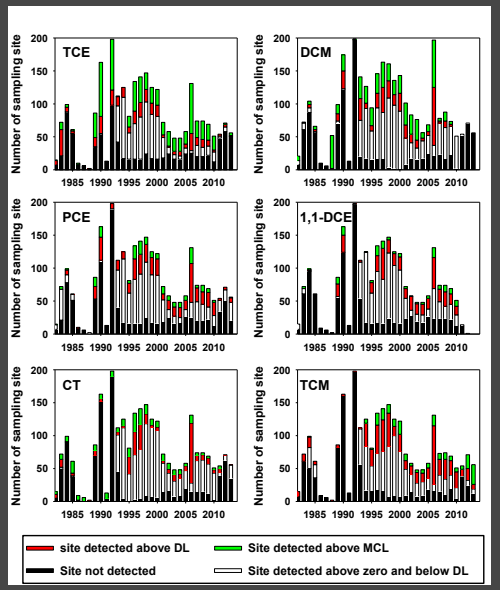
Project 4 Selected Results

- ✓ Spatiotemporal analysis of groundwater data reflects extensive contamination
- ✓ Refined spatiotemporal analysis show significant variability in the distribution of CVOCs





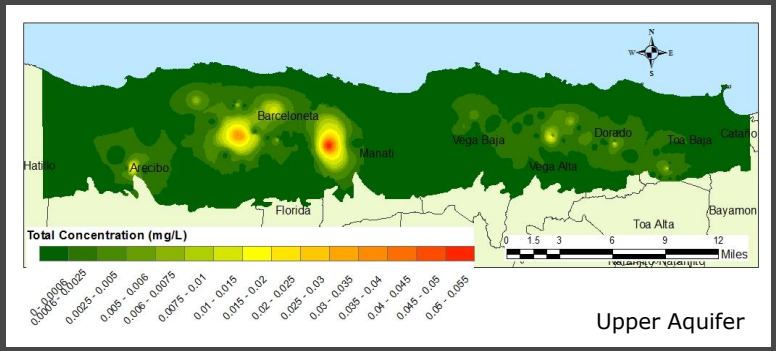
Padilla et al., 2015

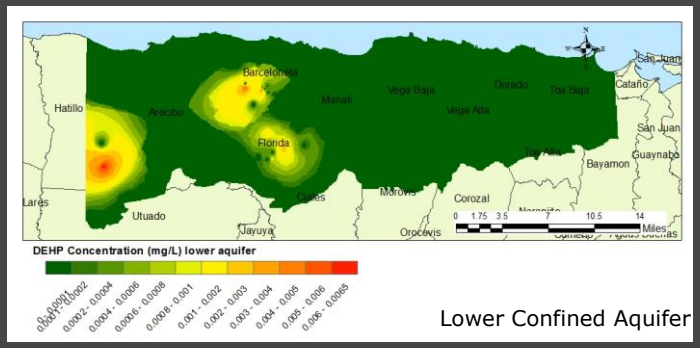


Yu et al., 2015

Project 4 Selected Results

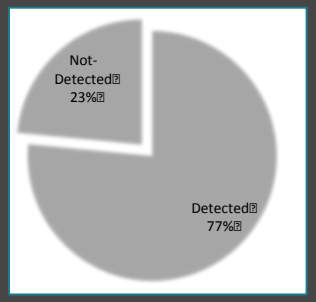
- ✓ Higher detection frequencies and concentrations of phthalates are associated with regions of highest aquifer permeabilities and sinkhole density



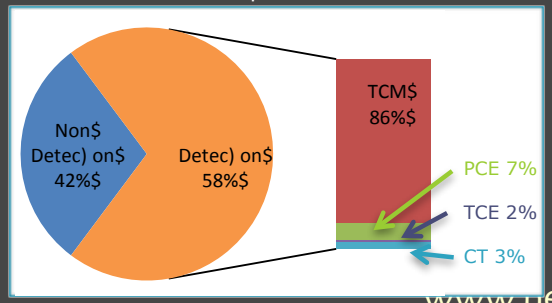


- ✓ Marked differences in detection frequencies and concentrations between source water and tap water

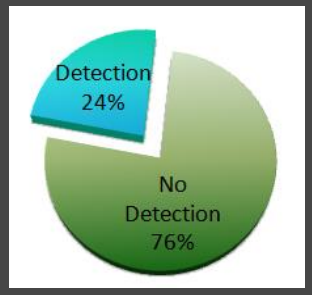
CVOC- Groundwater



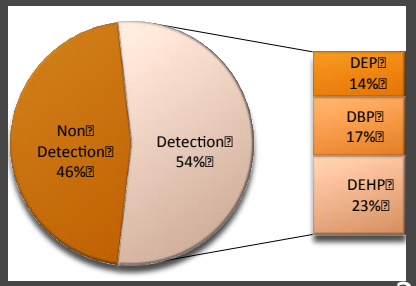
CVOC- Tap Water



Phthalate- Groundwater

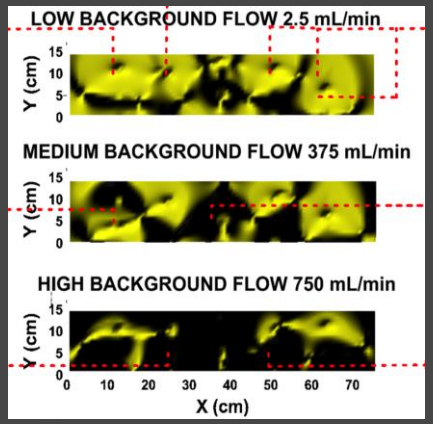


Phthalate- Tap Water

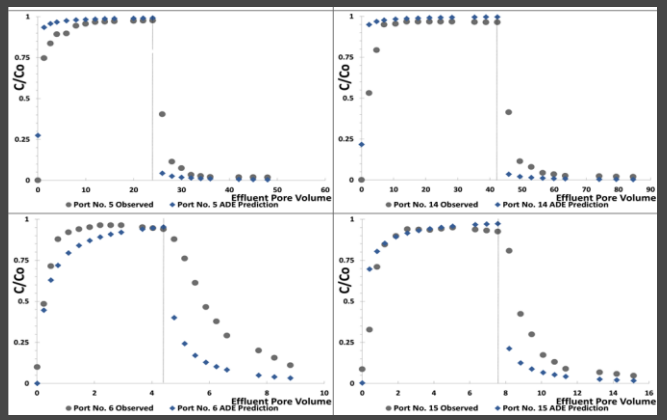


Project 4 Selected Results

- ✓ Laboratory-Scale
  - ✓ Develop statistical characterization of preferential flow paths and quantified transport parameters that are to be used for predictive purposes



(Anaya et al. 2014)

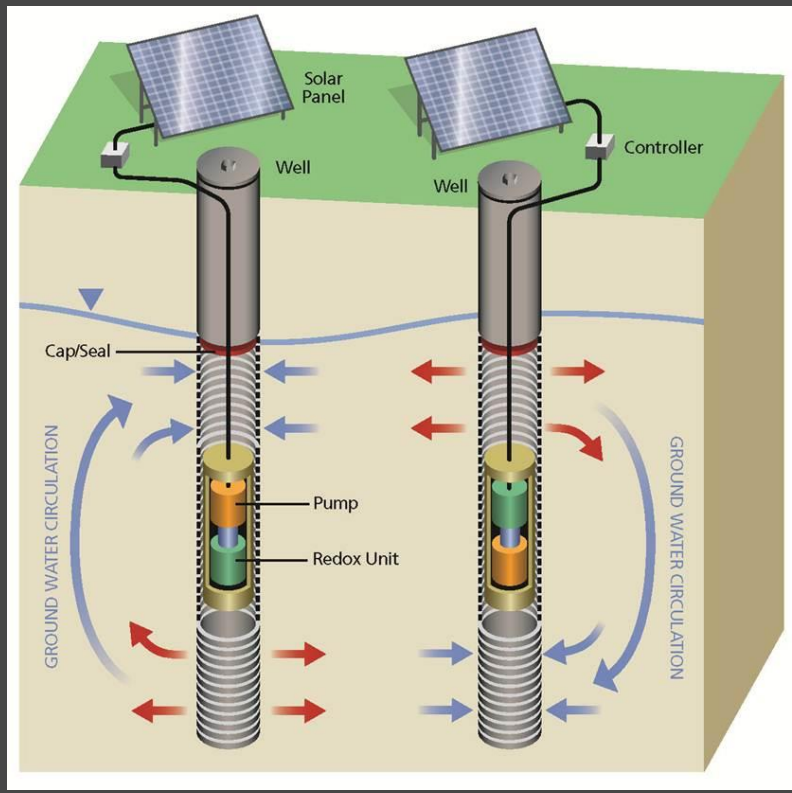


- ✓ Spring Watershed characterization
  - ✓ Translates what we learn from lab-scale experiments into what is happening at the field scale

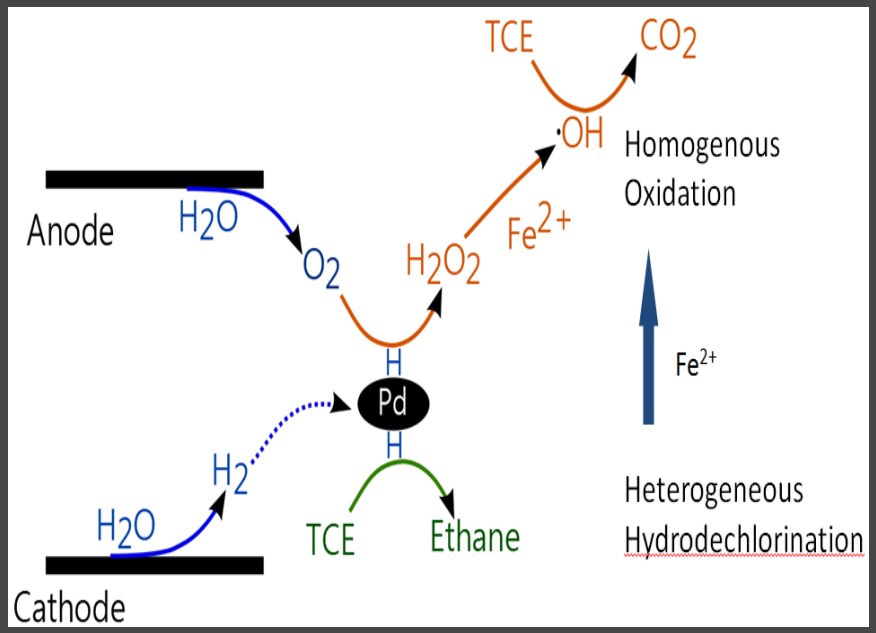
Project 5: Green Remediation by Solar Energy Conversion into Electrolysis in Groundwater

Leader: Akram Alshawabkeh, Northeastern Univ.

- Evaluate electrolysis for manipulating redox conditions in groundwater
- Evaluate transformation of TCE and other contaminants in pore fluid by electrolysis
- Assess toxicity evolution
- Engineer system for field implementation



Project 5 - Electrochemical Transformation Mechanisms



- Use electrolysis to promote oxidation in groundwater

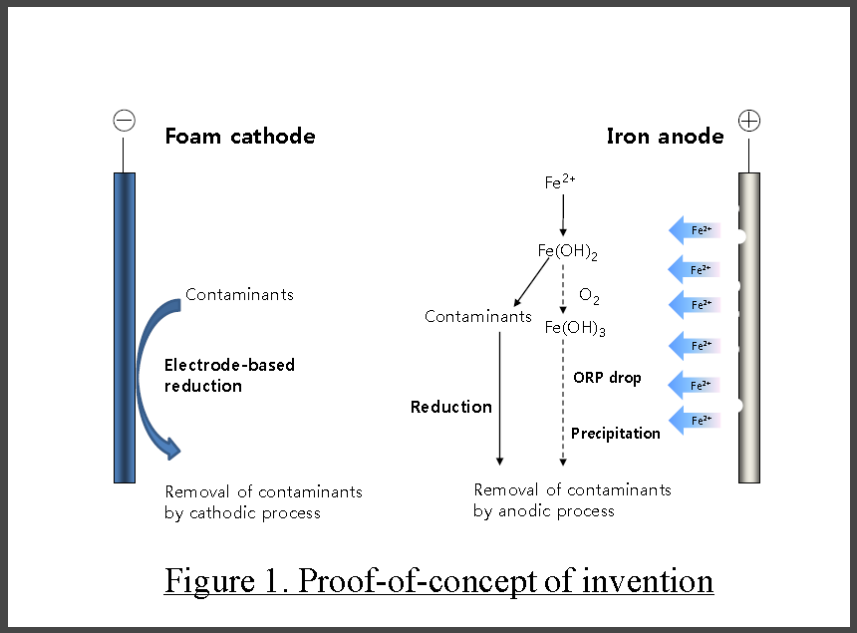
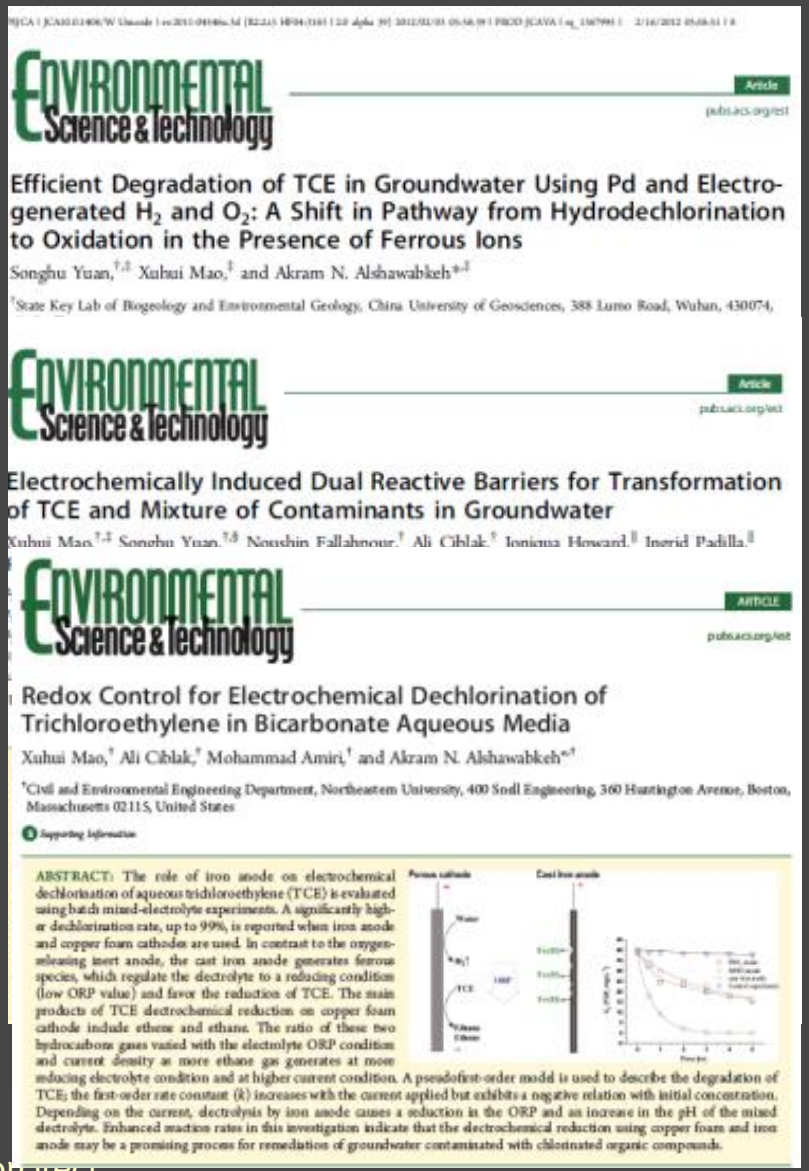


Figure 1. Proof-of-concept of invention

- Use electrolysis to promote reduction in groundwater

Project 5 Selected Results

- ✓ Transformation of all dissolved TCE from groundwater
- ✓ Delineation of transformation mechanisms
- ✓ Demonstrated simultaneous transformation of contaminant mixtures
- ✓ Patent application filed for novel two electrode remediation system
- ✓ Working on pilot-testing



ENVIRONMENTAL Science & Technology

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Efficient Degradation of TCE in Groundwater Using Pd and Electro-generated H_2 and O_2: A Shift in Pathway from Hydrodechlorination to Oxidation in the Presence of Ferrous Ions

Songhu Yuan,[†,‡] Xuhui Mao,[‡] and Akram N. Alshawabkeh*[,‡]

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ENVIRONMENTAL Science & Technology

Article

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Electrochemically Induced Dual Reactive Barriers for Transformation of TCE and Mixture of Contaminants in Groundwater

Xuhui Mao,[†,‡] Songhu Yuan,[†,§] Noushin Fallahpour,[†] Ali Ciblak,[†] Jonjqua Howard,[‖] Ingrid Padilla,[‖]

ENVIRONMENTAL Science & Technology

ARTICLE

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Redox Control for Electrochemical Dechlorination of Trichloroethylene in Bicarbonate Aqueous Media

Xuhui Mao,[†] Ali Ciblak,[†] Mohammad Amiri,[†] and Akram N. Alshawabkeh*[,†]

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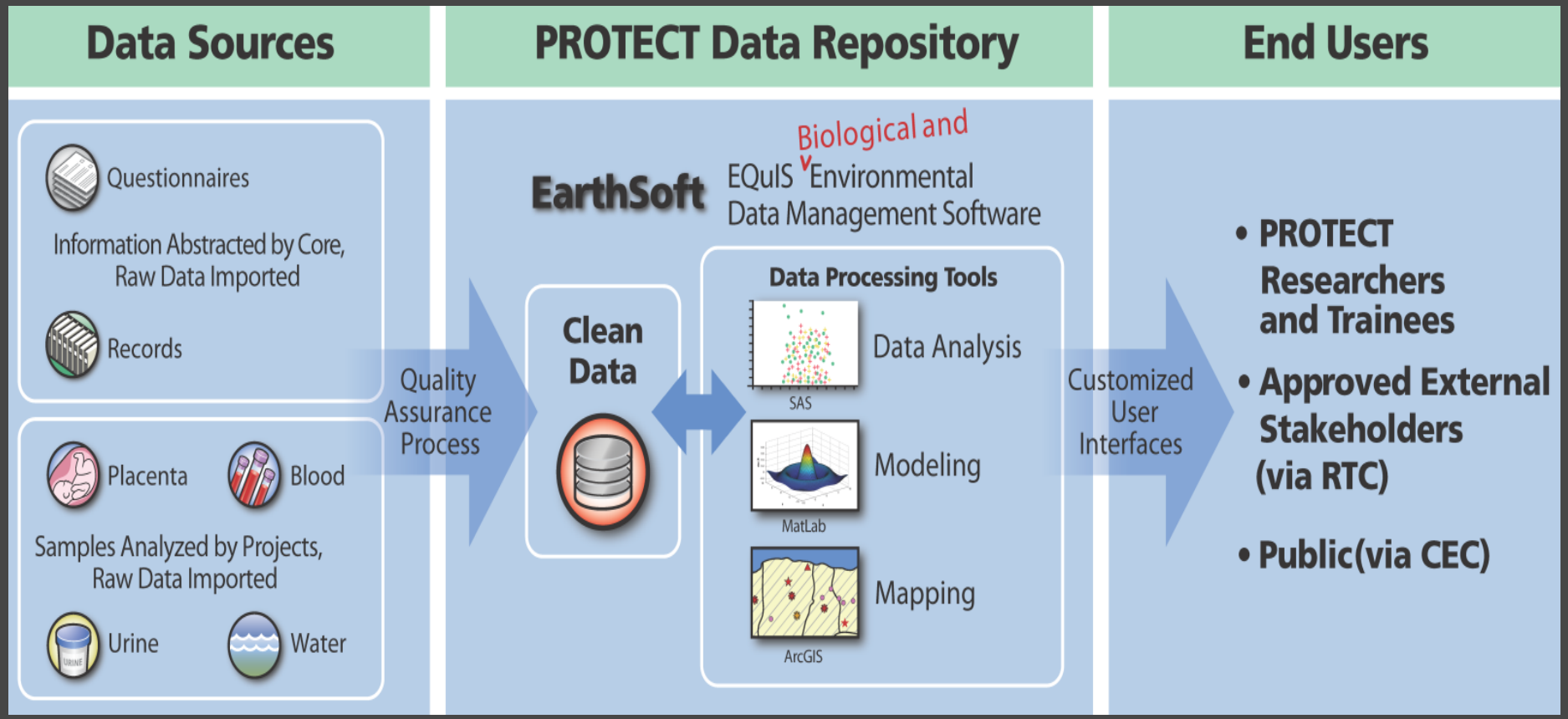
Supporting Information

ABSTRACT: The role of iron anode on electrochemical dechlorination of aqueous trichloroethylene (TCE) is evaluated using batch mixed-electrolyte experiments. A significantly higher dechlorination rate, up to 99%, is reported when iron anode and copper foam cathodes are used. In contrast to the oxygen-releasing inert anode, the cast iron anode generates ferrous species, which regulate the electrolyte to a reducing condition (low ORP value) and favor the reduction of TCE. The main products of TCE electrochemical reduction on copper foam cathode include ethene and ethane. The ratio of these two hydrocarbons gases varied with the electrolyte ORP condition and current density as more ethane gas generates at more reducing electrolyte condition and at higher current condition. A pseudo-first-order model is used to describe the degradation of TCE; the first-order rate constant (k) increases with the current applied but exhibits a negative relation with initial concentration. Depending on the current, electrolysis by iron anode causes a reduction in the ORP and an increase in the pH of the mixed electrolyte. Enhanced reaction rates in this investigation indicate that the electrochemical reduction using copper foam and iron anode may be a promising process for remediation of groundwater contaminated with chlorinated organic compounds.

Data Management and Modeling Core Leader: David Kaeli, Northeastern Univ.

EarthSoft



Data Management and Modeling Core - By the Numbers

- Human Subject Data
  - 3,193 total fields/participant; Presently **15** different forms
  - Close to ~1.5M records!
- Environmental Data
  - 1048 wells (14 of them include water contaminant data)
  - 35 springs (3 of them include water contaminant data)
  - Field data; 9 wells and 2 springs are sampled twice a year
  - Tap water data: 13 contaminants
- Targeted Exposure Data
  - 51 targeted chemicals * ~8 fields * # of participant
    - 19 Phthalates and Phenols
    - 18 Trace Metal
    - 14 Pesticides
- Non-targeted Biological Data
  - 5 fields, >1B data points in 6 urine samples
    - Mass-to-charge values
    - Data peaks

Community Engagement Core

Leaders: Carmen Velez Vega, UPR
Phil Brown, Northeastern Univ.

- PROTECT Wins the 2015 People's Choice Award at the EPA Community Involvement Training Conference
- PROTECT Researchers Partner with March of Dimes in San Juan
- The CEC has brought a number of community partners together to form a Community Advisory Board that include Ciudadanos en Defensa del Ambiente (CEDDA; Citizens for Environmental Defense), Ciudadanos del Karso (Citizens of the Karst), and COTICAM (Steering Committee for Environmental Quality).

Partners and Collaborators

- Collaboration with local stakeholders
- Health care professional groups
- Local Community Health Centers
- Environmental advocacy groups

SSEHRI
Social Science Environmental Health Research Institute

PryMed
Unidos por tu salud

CHS
CAMUY HEALTH SERVICES, INC

Manatí Medical Center

Centro de Salud
Lares / Quebradillas

M.C.H.C. INC.
IPA 026
Morovis Community Health Center, Inc.

march of dimes

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COTICAM

pr
BasuraCero
REDUCE • REUSA • RECICLA • COMPOSTA

CIUDADANOS DEL KARSO

Acknowledgments

NIH National Institute of Environmental Health Sciences
Your Environment. Your Health.

PROTECT
Puerto Rico Testsite for Exploring Contamination Threats

EarthSoft

DEPARTAMENTO DE SALUD
GOBIERNO DE PUERTO RICO

USGS
science for a changing world

EPA

CDC

SILENT SPRING INSTITUTE

http://www.northeastern.edu/protect/

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For More Information

- Website: www.northeastern.edu/PROTECT
- Email: protect-info@coe.neu.edu
- or contact Rachel Grashow
  Phone: (617) 373-4153
  r.grashow@neu.edu

- Previous CLU-IN presentation:

Integrating Data from Multidisciplinary Research, Session I: Introducing the Big Picture
Sponsor: NIEHS SRP
https://clu-in.org/conf/tio/IntegratingData1/

Upcoming Conferences

- NIEHS SRP Annual Conference; Nov. 18 – 20, 2015; San Juan, PR
  - http://www.northeastern.edu/srp2015/
- Karst, Groundwater Contamination & Public Health; Jan 27 – 30, 2016; San Juan, PR
  - http://karstwaters.org/conferences/kgcph/