Health Effects and Geochemistry of Arsenic: The Columbia University NIEHS Superfund Research Program

NIEHSSRP

http://superfund.ciesin.columbia.edu Follow us on Twitter: @Columbia_SRP

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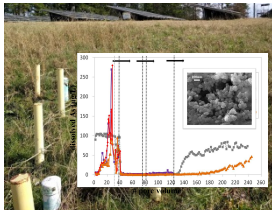
Habibul Ahsan, Lex van Geen and local team at the HEALS clinic in Araihazar, Bangladesh

Joe Graziano with Bangladesh Children Study Participants

Administrative Core

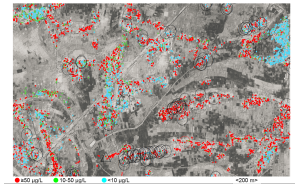
Director Ana Navas-Acien
Co-Director Alexander van Geen

Research Projects



CU SRP Scientists establishing the efficacy of magnetite-based As groundwater remediation (inset graph and micrograph), a tool we hope to apply at the Lot 86 NPL site (shown in photo).

CU SRP Scientists with HEALS Field Staff in Bangladesh at 12-year Anniversary Celebration of Study



As Concentrations in Tubewells Araihazar, Bangladesh

Project 1: Health Effects of As Longitudinal Study (HEALS)
PI: Habibul Ahsan

Evaluate health effects from As in drinking water in Araihazar, Bangladesh

- 35,000 men & women interviewed every 2-3 years
- Dedicated medical clinic
- Study impact of As exposures on: Cardiovascular disease and diabetes Non-malignant respiratory disease
- Contribute to the dose-response assessment through a pooled analysis with 11 other cohorts worldwide

Project 2: Arsenic and B-vitamins in Children (ABC study)
PI: Mary Gamble

Placebo-controlled RCT of folate plus B12 supplementation on As internal dose and cognitive function in children

- Elucidate the effect of folate+vitamin B12 on As methylation and blood As levels in children (Aim 1)
- Explore their effect on cognitive function (Aim 2)
- Assess the association of choline on Aim 1 and 2 outcomes
- Replicate association of dietary folate, B12 and choline on As methylation in adolescents from the Strong Heart Study

Project 3: Enhanced Remediation at US As-contaminated Sites
PI: Benjamin Bostick

Examine different As remediation approaches

- To understand the mechanisms of arsenic dissolution and retention in environments affected by arsenic contamination.
- To develop, optimize and pilot arsenic remediation in groundwater

1. Oxalate-based enhanced pump-and-treat remediation of arsenic
2. Magnetite-based arsenic immobilization
- Piloting biogenic magnetite immobilization at Lot86 NPL site (NC) and Yinchuan, China.

Project 4: Resilience of Low-As Aquifers and their Role in Reducing Human Exposure
PI: Alexander van Geen

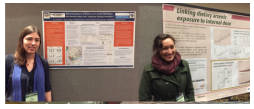
Lower As exposure in HEALS

- Test hh wells within study area using both lab measurements & field kits
- Monitor 110 deep community wells

Understand processes that threaten quality of GW in current low As aquifers

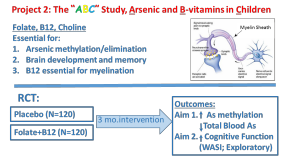
- Investigate a handful of community well failures using geophysical, hydrological, & biogeochemical approaches

Educational Interventions with health education clowns



Trainees Sara Flanagan and Tiffany Sanchez presenting at NIEHS Fest

Outreach with health care providers to launch As monitoring in medical practices in Hunterdon New Jersey



Cores

Core A: Training Core
PIs: Joseph Graziano Brian Mailloux

Educate trainees in the interdisciplinary research methods and strategies for environmental health and engineering sciences

Anne Bozack, 2017 K.C. Donnelly Externship Award

Anne Nigra, PhD student and CU SRP trainee

Barnard College Arsenic Awareness Student Videos

Core B: Integrated Science Support Core
PIs: Joseph Graziano Richard Buchsbaum

Precisely measure metals & metabolites in biospecimens

Provide safe, secure relational data management

Trace metal core at Columbia University Mailman School of Public Health

As Testing in Maine Well Water

Core C: Biogeochemistry
PI: Alexander van Geen

Measure metals, dissolved organic carbon, reactive organic acids & more in groundwater and sediment samples

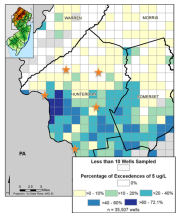
Field kit testing and e-data entry in Araihazar by study staff

Core D: Hydrogeology
PI: Peter Schlosser

Provide the tools and expertise to collect and interpret hydrogeological data

Core E: Community Engagement
PI: Yan Zheng

Develop tools, resources & strategies to build the capacity of individuals, communities & government partners to reduce exposure to As from private wells in ME, NJ & MN



★ Participating medical practices in As monitoring in Hunterdon, NJ

Core F: Research Translation Core (RTC)
PIs: Sandra Baptista Steven Chillrud

Augmenting & accelerating the impact of our Center's basic & applied science on public policies, regulations & human behavior

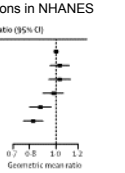
Brochure to offer As testing in medical practices in Hunterdon, NJ

Estimated urinary DMA concentrations in NHANES

Year	N	Geometric mean	Geometric mean ratio (95% CI)
2003–04	1275	3·01 (2·87–3·15)	1·00 (reference)
2005–06	1408	3·10 (3·06–3·15)	1·03 (0·95–1·12)
2007–08	1595	3·11 (3·07–3·15)	1·03 (0·94–1·13)
2009–10	1763	2·93 (2·89–2·97)	0·98 (0·90–1·06)
2011–12	1472	2·64 (2·61–2·68)	0·88 (0·80–0·96)
2013–14	1644	2·49 (2·45–2·52)	0·83 (0·76–0·90)

p value for trend p<0·001

Source: Nigra et al. Lancet Public Health 2017



Data server in Araihazar, Bangladesh

Transdisciplinary Data Entry

Safe well

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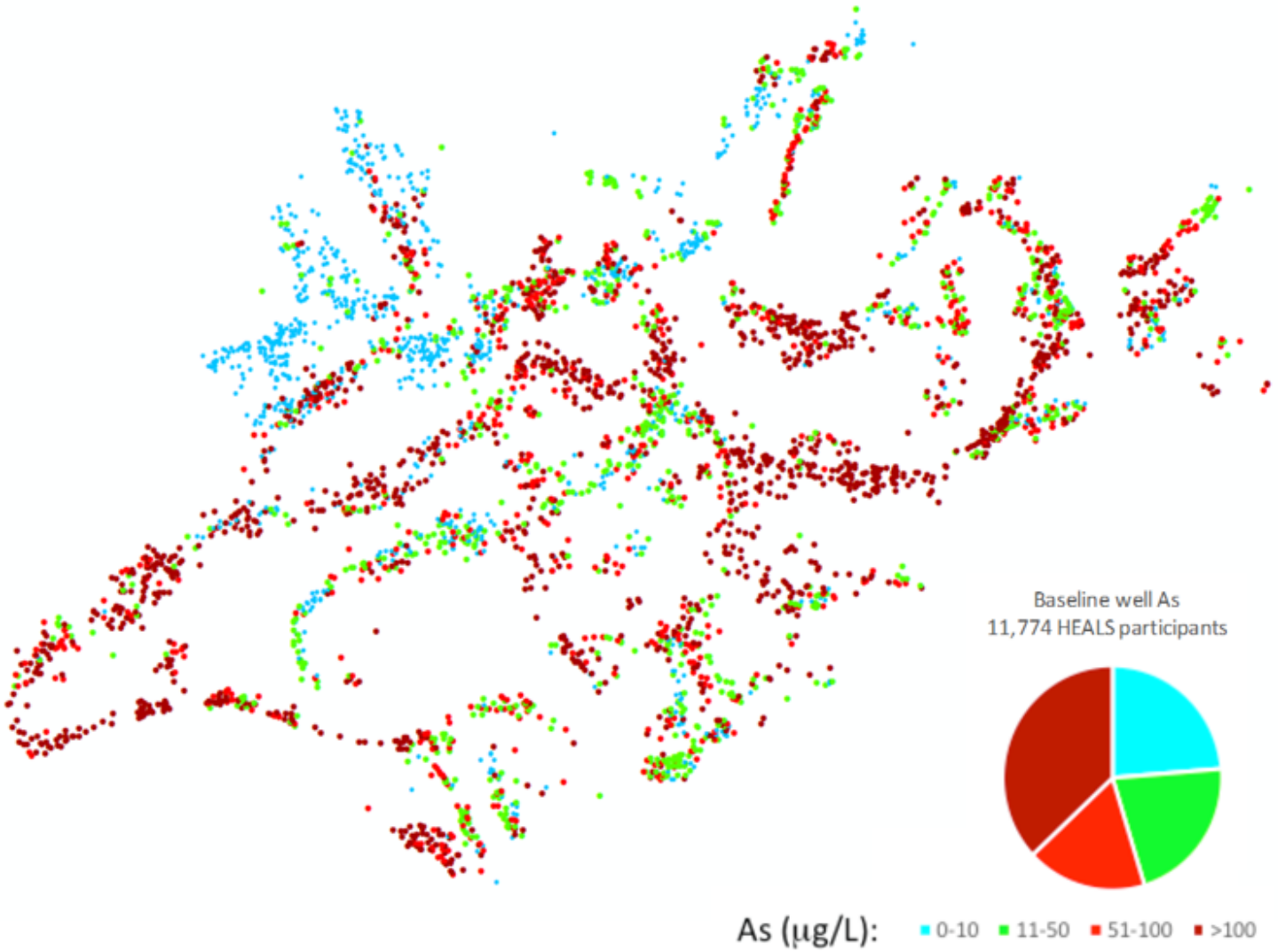
Project 1: Health Effects of As Longitudinal Study (HEALS)

PI: Habibul Ahsan

Map of 4,142 primary wells of HEALS participants in 25 km^2 area of Araihazar at 2000-01 baseline



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PI: Habibul Ahsan

	N	Enrollment years	In-person Home Visits (Every 2-3 years)**						
			Baseline	FU-1	FU-2	FU-3	FU-4	FU-5	FU-6
Original cohort	11746	2000-02	√ Q, water, CE, blood, urine	√ Q, CE, urine, Dx	√ Q, CE, urine, Dx	√ Q, CE, urine, Dx	√ Q, CE, Dx	√ Q, CE, urine*, Dx	√ Q, water, CE, urine, Dx

BMJ

2011;342:d2431

Arsenic exposure from drinking water and mortality from cardiovascular disease in Bangladesh: prospective cohort study

Water As	HR (95%CI) for CHD
<12.0 µg/L	1.00 (ref)
12.1-62.0	1.22 (0.65, 2.32)
62.1-148.0	1.35 (0.71, 2.57)
>148.1	1.92 (1.07, 3.43)
Per SD (115 µg/L)	1.29 (1.10, 1.52)

Urine As	HR (95%CI) for CHD
< 106 µg/g creat.	1.00 (ref)
106-199	1.29 (0.74, 2.27)
199-352	1.53 (0.83, 2.82)
>352	2.06 (1.14, 3.72)
Per SD (282 µg/g)	1.26 (1.12, 1.42)

Adjusted for age, sex, BMI, smoking status, education
CHD: coronary heart disease

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Project 1: Health Effects of As Longitudinal Study (HEALS)

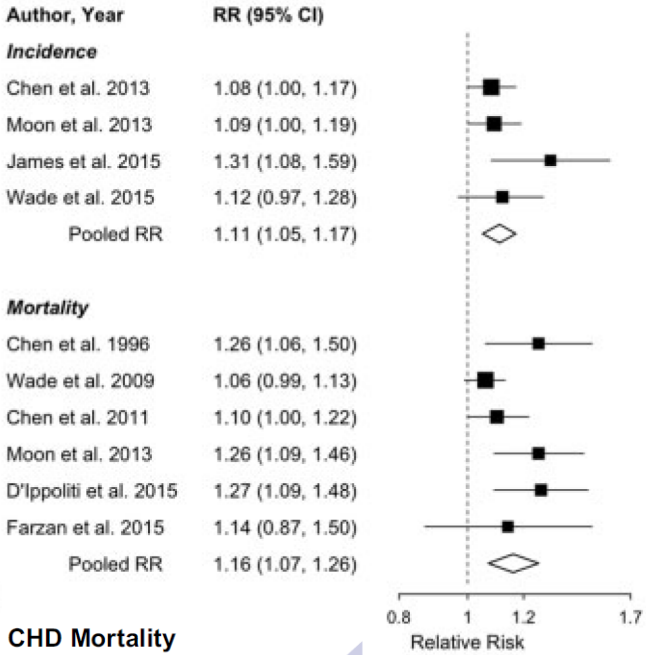
PI: Habibul Ahsan

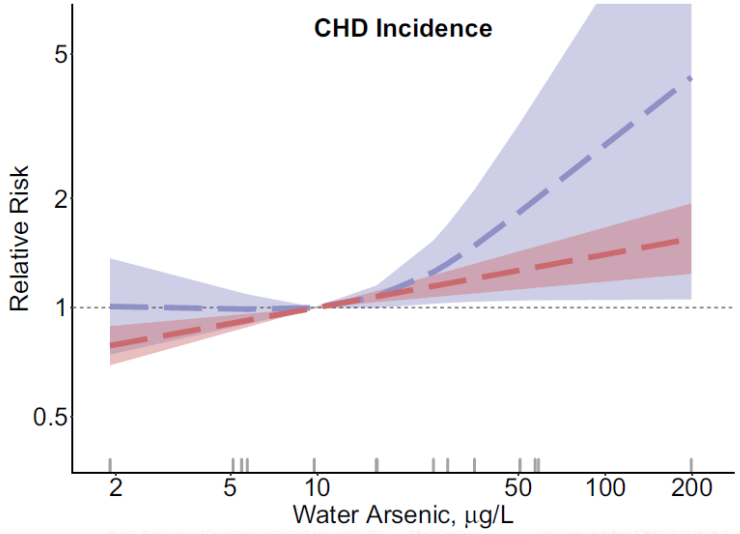
International Journal of Epidemiology, 2017, 1924–1939
doi: 10.1093/ije/dyx202
Advance Access Publication Date: 23 September 2017
Original article

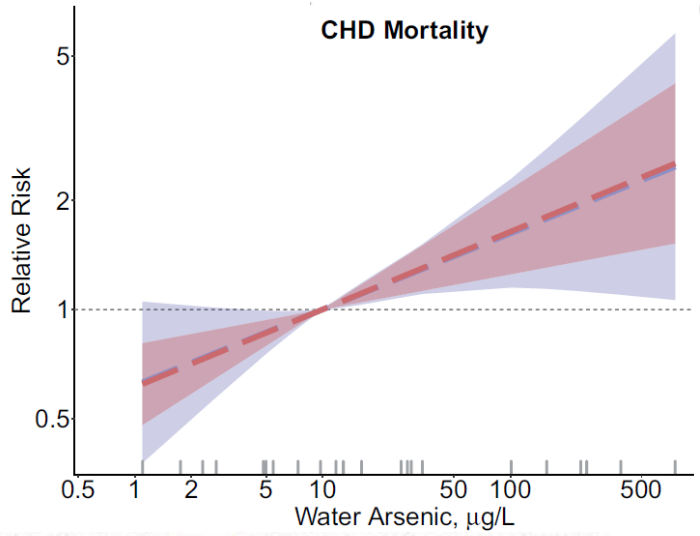
IEA Hazardous Substances

A dose-response meta-analysis of chronic arsenic exposure and incident cardiovascular disease

Katherine A Moon,[1,2*] Shilpi Oberoi,[3] Aaron Barchowsky,[3] Yu Chen,[4] Eliseo Guallar,[1] Keeve E Nachman,[2] Mahfuzar Rahman,[5] Nazmul Sohel,[6] Daniela D'Ippoliti,[7] Timothy J Wade,[8] Katherine A James,[9] Shohreh F Farzan,[10] Margaret R Karagas,[11] Habibul Ahsan[12] and Ana Navas-Acien[1,2,13]







Dose-Response Model: log-linear (constant slope) non-linear (flexible slope)

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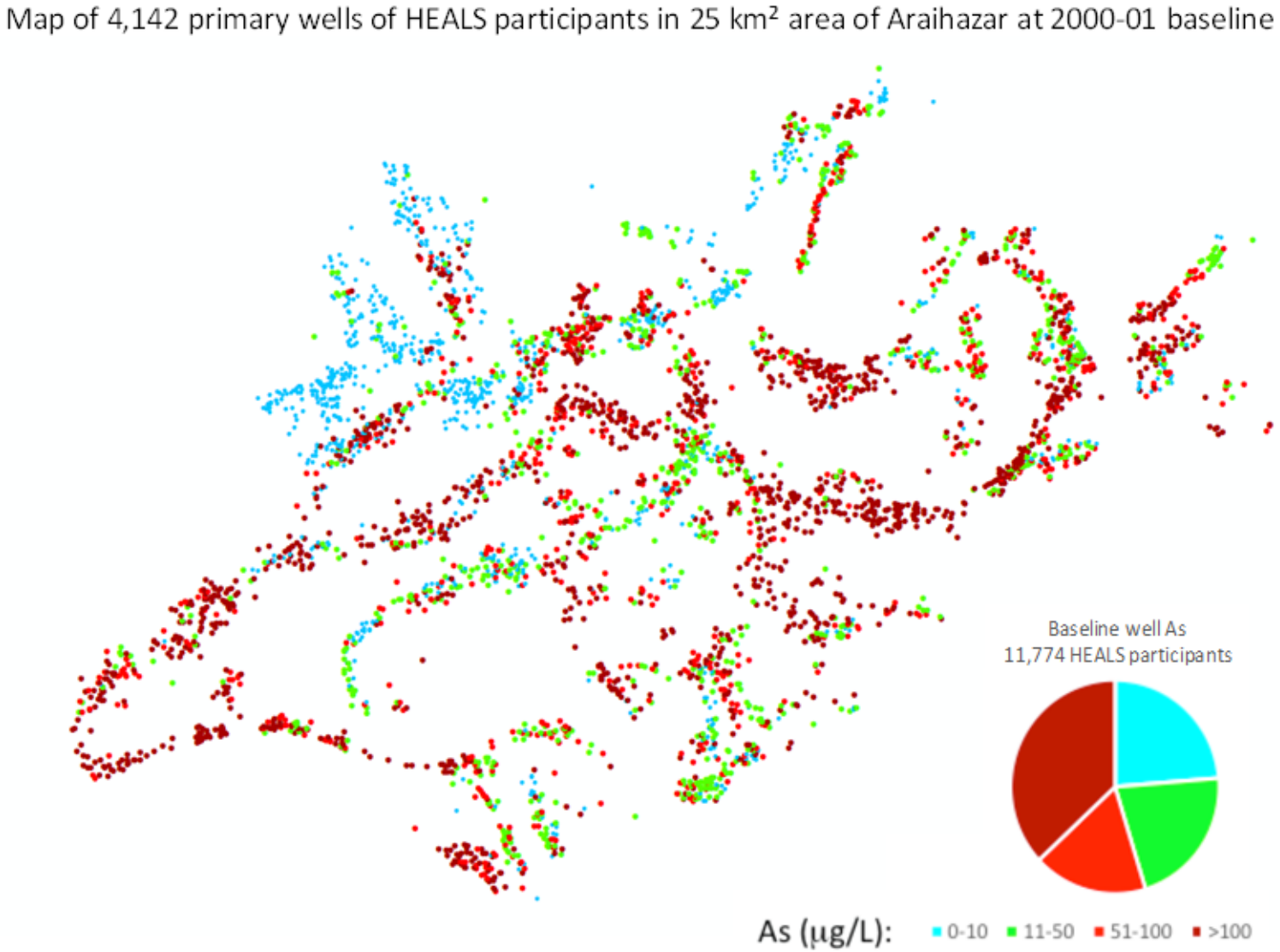

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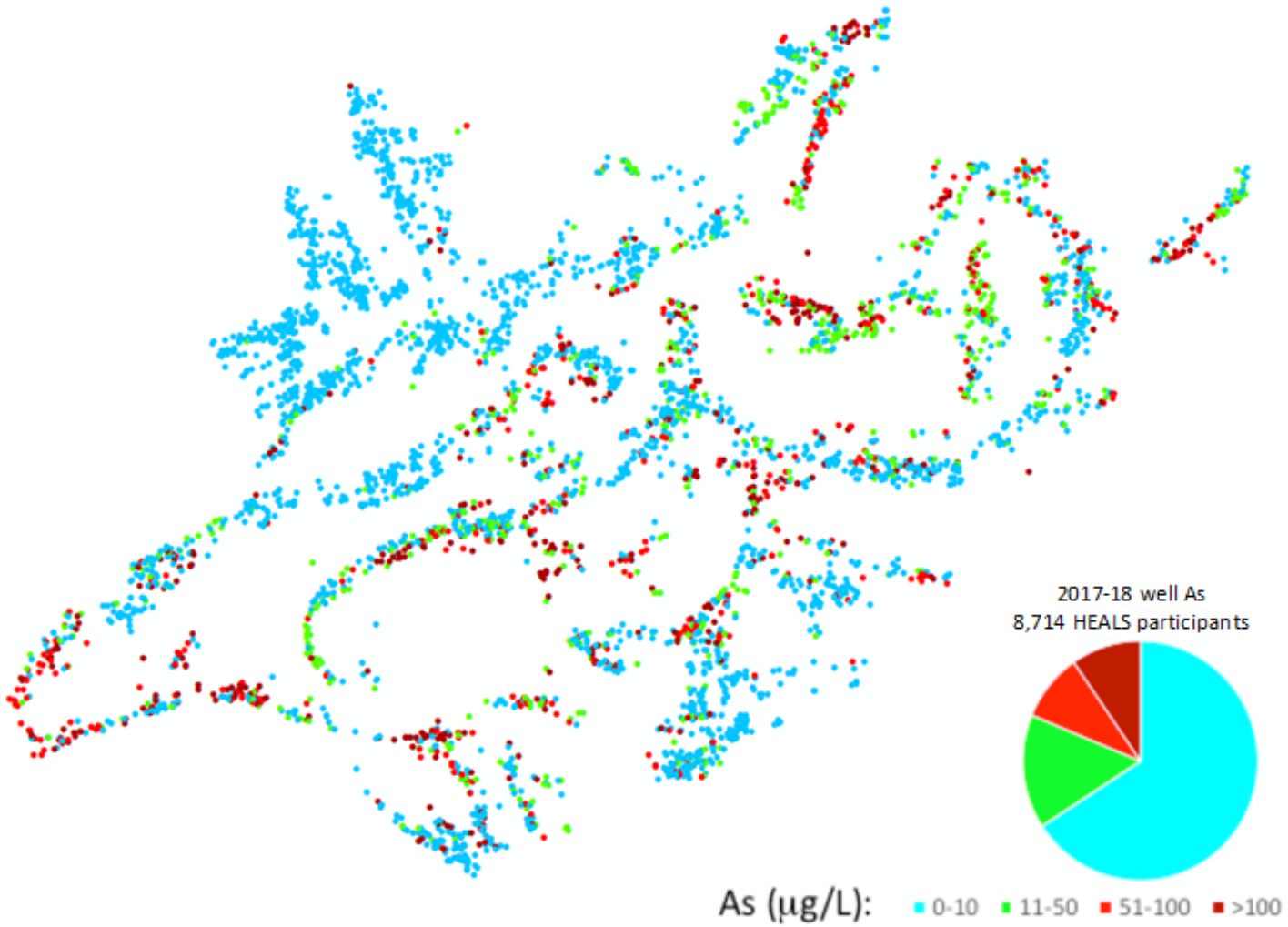
Project 1: Health Effects of As Longitudinal Study (HEALS)

PI: Habibul Ahsan

Map of 4,229 primary wells of HEALS participants in Araihazar at 2017-18 follow-up



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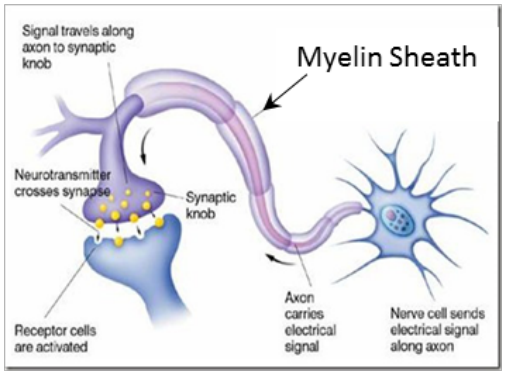
Project 2: Arsenic and B-vitamins in Children (ABC study)
PI: Mary Gamble

Folate, B12, Choline

Essential for:

1. Arsenic methylation/elimination
2. Brain development and memory
3. B12 essential for myelination



RCT:

- Placebo (N=120)
- Folate+B12 (N=120)

→ 3 mo.intervention →

Outcomes:

Aim 1. ↑ As methylation
↓Total Blood As

Aim 2. ↑ Cognitive Function (WASI; Exploratory)

As of 9/1/2018:

- **146 children have been enrolled**
- **102 children completed the 12 week intervention**

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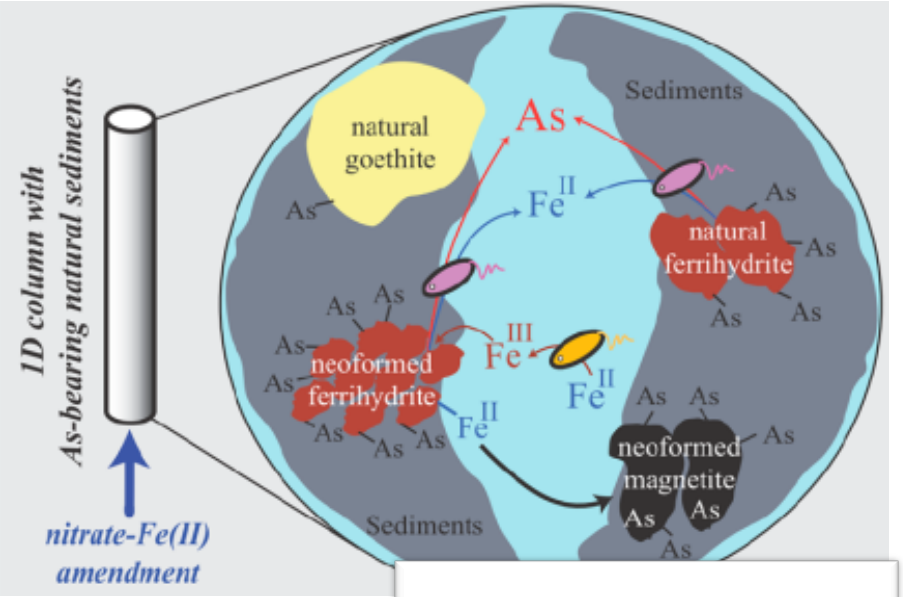
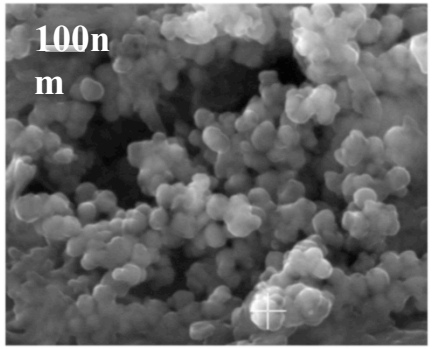
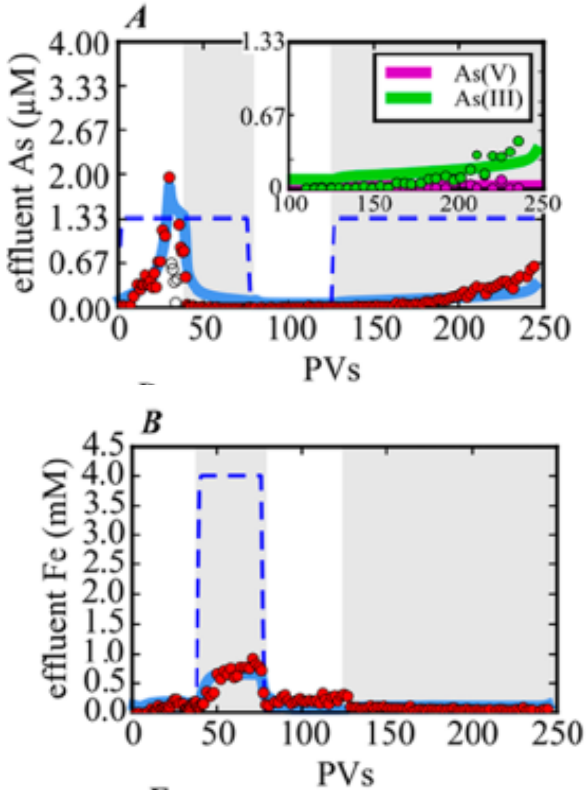
Project 3: Enhanced Remediation at US As-contaminated Sites
PI: Benjamin Bostick

Optimizing and Implementing *in situ* formation of biogenic magnetite formation for As remediation at NPL Sites







Sun et al. (2018) Environ Sci. Technol.

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Project 3: Enhanced Remediation at US As-contaminated Sites
PI: Benjamin Bostick

- North Carolina State University Lot 86 Landfill Site
  - to investigate feasibility and mechanisms of magnetite-based approach
- Yinchuan Plain (*Not in this proposal but related to methodology):*
  - Arsenic concentrations decreased by about 100x, from 500 ppb to <5 ppb.
  - Rate of pumping affects As removal considerably

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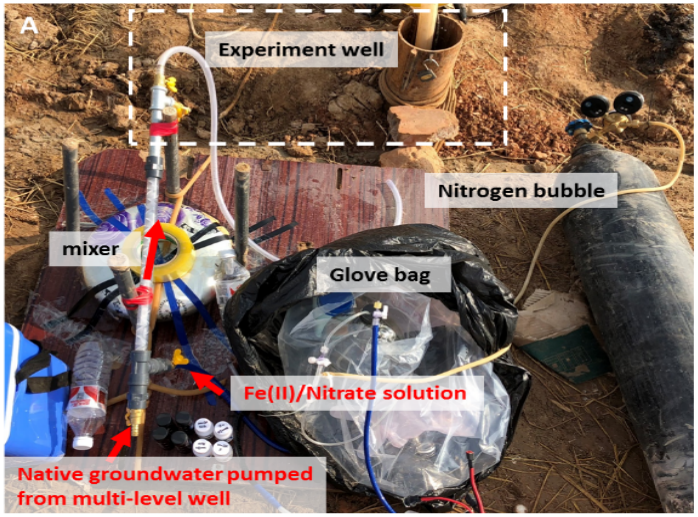
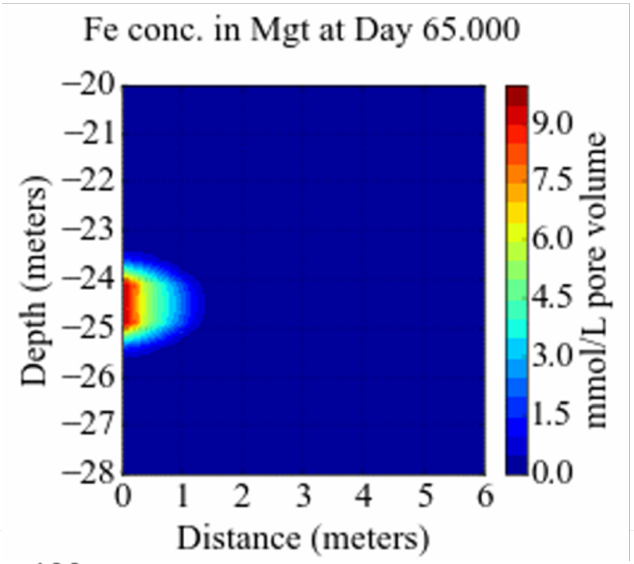
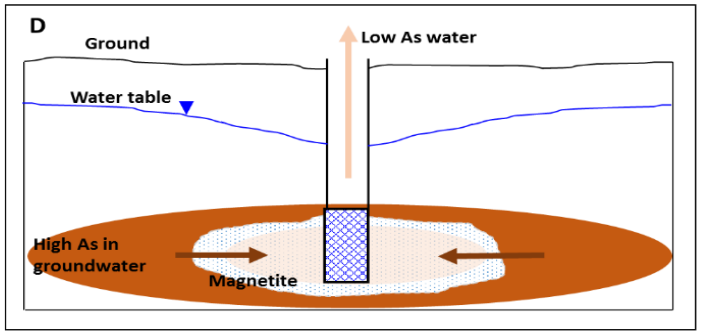
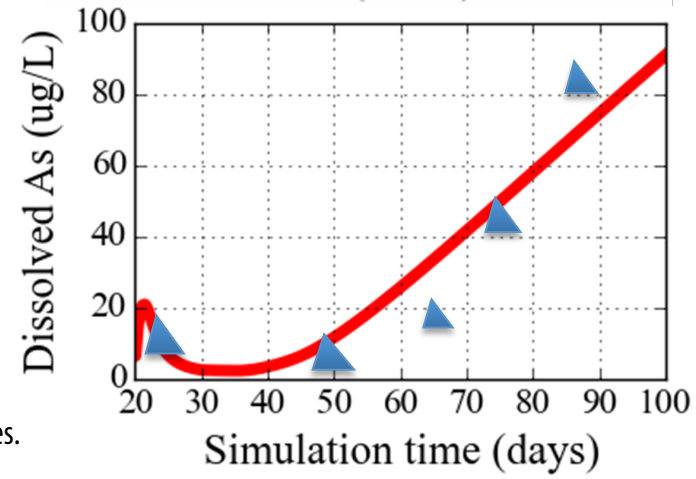
Project 3: Enhanced Remediation at US As-contaminated Sites
PI: Benjamin Bostick









Push-Pull experiment in high-As well.

- As removal was significant for approximately 50 injection volumes.
- Model results are similar to measured values (triangles, approximated).

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Lot 86 Field Studies

MT3DMS for tracers,
refine hydrological parameters

↓

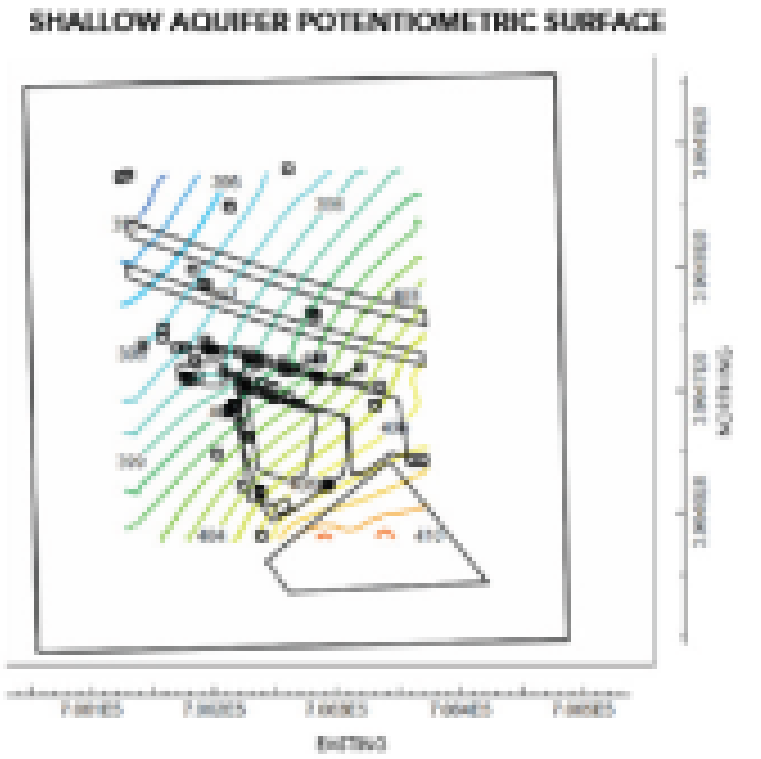
field tracer test

↓

MT3DMS, field injection test

↓

broad applicability



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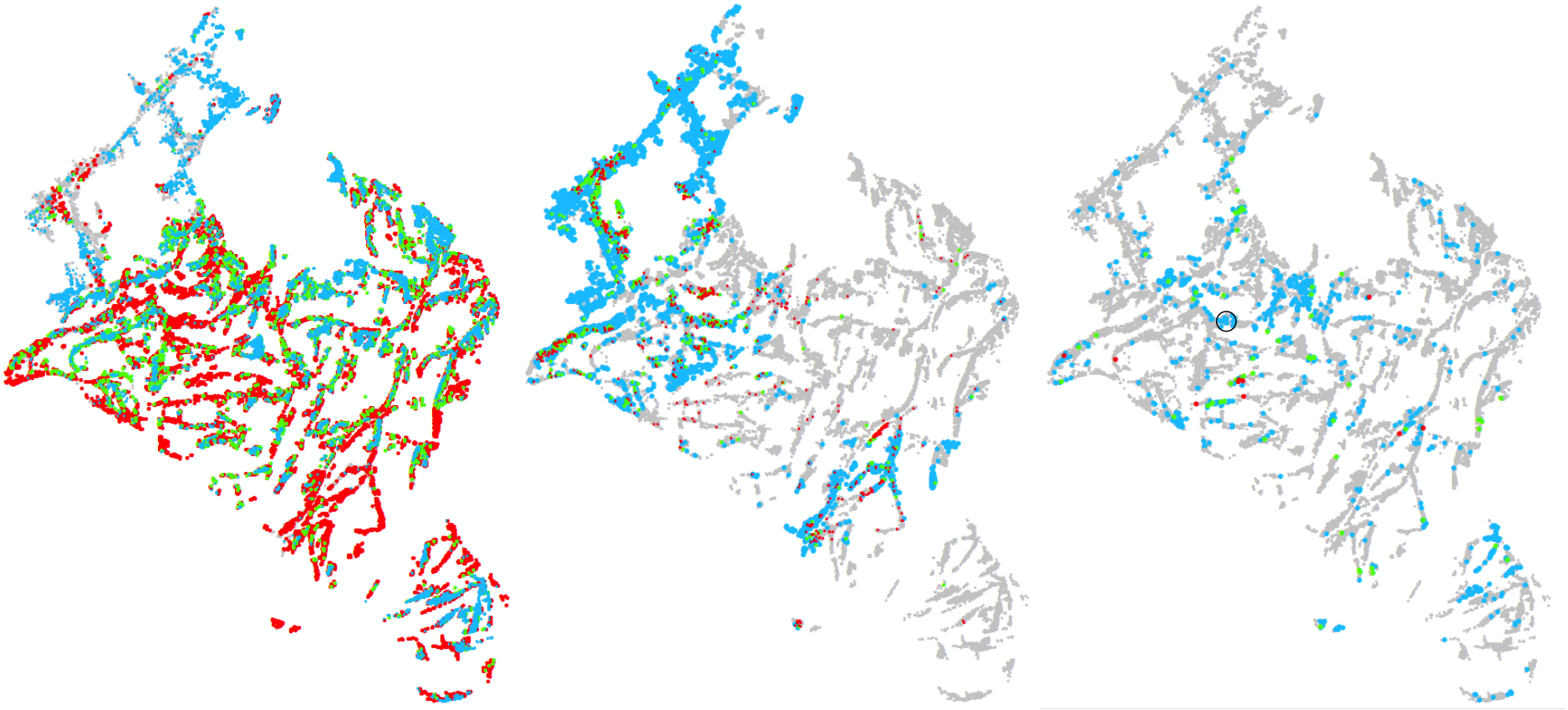
Project 4: Resilience of Low-As Aquifers and their Role in Reducing Human Exposure

PI: Alexander van Geen

Shallow wells (10-45 m) Intermediate wells (45-90 m) Deep wells (90-300 m)



Health Effects and Geochemistry of Arsenic: The Columbia University NIEHS Superfund Research Program

Project 4: Resilience of Low-As Aquifers and their Role in Reducing Human Exposure
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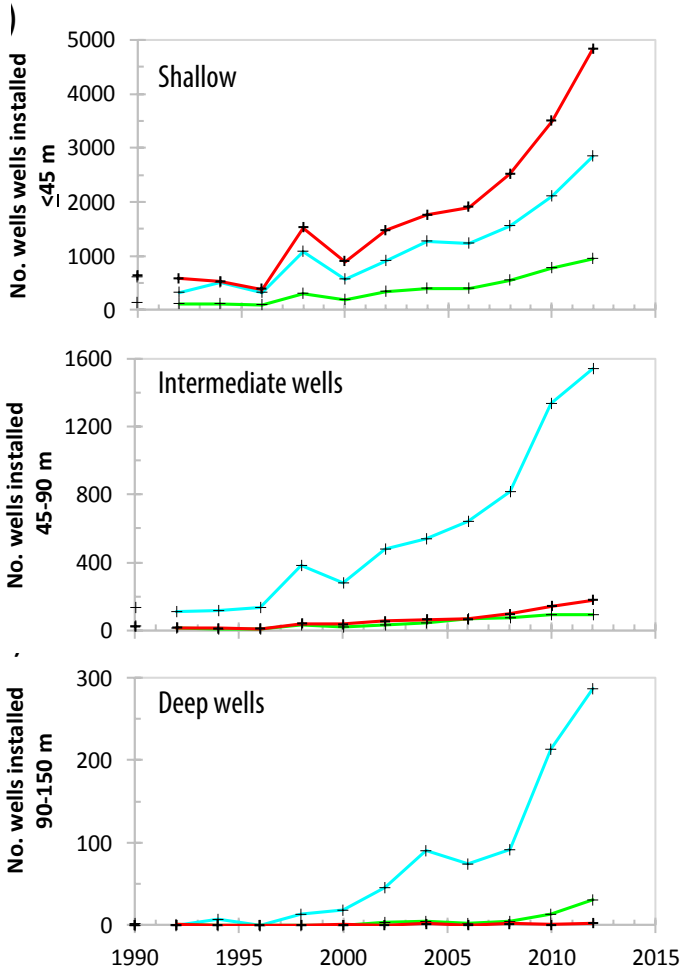
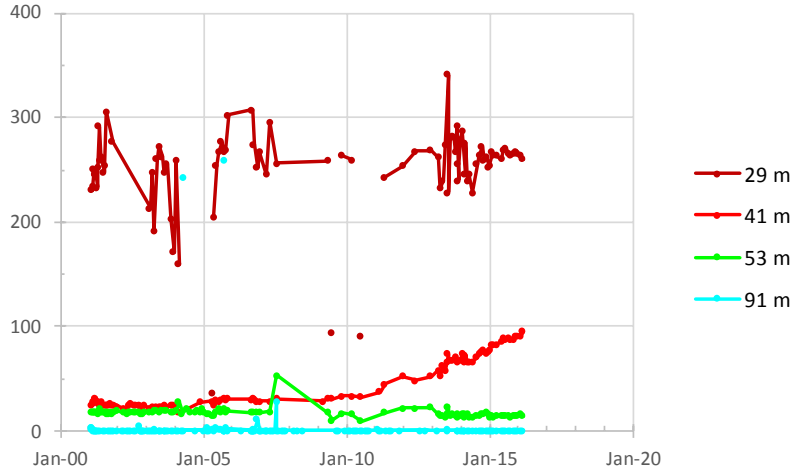
Many intermediate wells have been installed. Are they likely to remain safe?





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Project 4: Resilience of Low-As Aquifers and their Role in Reducing Human Exposure

PI: Alexander van Geen

Could exported methane rather dissolved organic carbon pose the main threat to low-As aquifers?

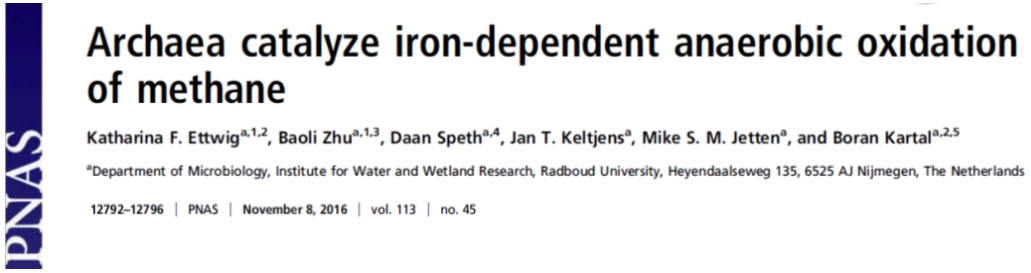
Relevance to landfills in US

Reduction of Fe-oxides containing As by dissolved/sedimentary organic carbon

$$CH_2O + 4\ Fe(OH)_3 + 7\ H^+ \Rightarrow 4\ Fe^{2+} + HCO_3^- + 10\ H_2O$$

Reduction of Fe-oxides containing As by dissolved/sedimentary organic carbon

$$CH_4 + 8\ Fe(OH)_3 + 15\ H^+ \Rightarrow HCO_3^- + 8Fe^{2+}\ 21H_2O$$



PNAS

Archaea catalyze iron-dependent anaerobic oxidation of methane

Katharina F. Ettwig[a,1,2], Baoli Zhu[a,1,3], Daan Speth[a,4], Jan T. Keltjens[a], Mike S. M. Jetten[a], and Boran Kartal[a,2,5]

[a]Department of Microbiology, Institute for Water and Wetland Research, Radboud University, Heyendaalseweg 135, 6525 AJ Nijmegen, The Netherlands

12792–12796 | PNAS | November 8, 2016 | vol. 113 | no. 45

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Core E: Community Engagement
PI: Yan Zheng
Core F: Research Translation Core (RTC)
PIs: Sandra Baptista and Steven Chillrud

Maine Legislation to Support Education and Outreach for Private Well Water Testing

- LD 454 (*An Act to Ensure Safe Drinking Water for Families in Maine*) was passed by the House (113-33) and the Senate (35-0) on June 19/2017.
- Columbia SRP studies on child IQ, arsenic testing, and arsenic treatment were cited repeatedly in testimony in favor of the bills and by legislators during floor debates.

Targeted testing through healthcare providers in Hunterdon County, NJ:

- Grand rounds and staff talks followed by flyers, posters and test kits at medical practices
- Private wells on medical records
- Earth Day testing campaign including targeted messages through online patient portal, Facebook Q&A, billboards
    - 457 test kits requested, 67% returned, ~10% water samples > NJ standard of 5 µg/L

Health Effects and Geochemistry of Arsenic: The Columbia University NIEHS Superfund Research Program

Core F: Research Translation Core (RTC)
PIs: Sandra Baptista and Steven Chillrud

The effect of the Environmental Protection Agency maximum contaminant level on arsenic exposure in the USA from 2003 to 2014: an analysis of the National Health and Nutrition Examination Survey (NHANES)

Anne E Nigra, Tiffany R Sanchez, Keeve E Nachman, David E Harvey, Steven N Chillrud, Joseph H Graziano, Ana Navas-Acien

Summary

Background In 2006, the current US Environmental Protection Agency (EPA) maximum contaminant level for arsenic in public water systems (10 µg/L) took effect. We aimed to assess national trends in water arsenic exposure in the USA, hypothesising that urinary arsenic concentrations would decrease over time in individuals using public water systems but not in those using well water (which is not federally regulated). We further estimated the expected number of avoided skin or lung and bladder cancer cases.

Lancet Public Health 2017; 2: e513–21
Published Online October 22, 2017
http://dx.doi.org/10.1016/S2468-2667(17)30195-0

Urine DMA concentrations not derived from food or smoking in NHANES

Estimated Year	N	Geometric mean	Geometric mean ratio (95% CI)
Public water			
2003–04	1275	3·01 (2·97–3·05)	1·00 (reference)
2005–06	1406	3·10 (3·06–3·15)	1·03 (0·95–1·12)
2007–08	1595	3·11 (3·07–3·15)	1·03 (0·94–1·13)
2009–10	1763	2·93 (2·89–2·97)	0·98 (0·90–1·06)
2011–12	1472	2·64 (2·61–2·68)	0·88 (0·80–0·96)
2013–14	1644	2·49 (2·45–2·52)	0·83 (0·76–0·90)
		p value for trend p<0·001	
Private wells			
	N	Geometric mean	Geometric mean ratio (95% CI)
	125	2·38 (2·28–2·47)	1·00 (reference)
	292	2·99 (2·88–3·11)	1·26 (1·04–1·51)
	192	2·63 (2·53–2·73)	1·10 (0·91–1·34)
	248	2·63 (2·53–2·73)	1·11 (0·94–1·30)
	182	2·27 (2·18–2·36)	0·95 (0·80–1·13)
	161	2·59 (2·50–2·70)	1·09 (0·79–1·52)
		p value for trend p=0·351