Columbia Universtiy 2016 Annual Updates

Health Effects and Geochemistry of Arsenic and Manganese
PI – Joseph Graziano

OVERALL CENTER HIGHLIGHTS:

Highlight #1:

Magnetite formation shows promise for remediation of groundwater arsenic contamination (Projects 4 and 5)

Projects 4 and 5 have been developing methods that can be used in field settings to remediate groundwater arsenic contamination. This year, we have published new research that establishes the viability of this technique in open (column) systems typical of natural environments (Sun et al., 2016). This manuscript shows that:

(1) Even background levels of organic carbon added to sediments as organic acids from the Dover Landfill (Dover NH) Superfund site can stimulate Fe(III) reduction and As release.

(2) Low levels of nitrate and ferrous iron can react through biological processes to produce a mixture of magnetite and ferrihydrite, both of which accumulate as dispersed colloids throughout the sediment matrix.

(3) Arsenic is efficiently removed from solution after magnetite formation, for prolonged periods and even under reducing conditions that liberated As prior to treatment.

Translation: An immediate outcome of this collaboration is that we are working to scale up this result in field trials at the Lot 86 Superfund site (Raleigh, NC) and the USGS Cape Cod site (Cape Cod, MA) in the coming year to test the efficacy of nitrate injections in the field as a means of remediating groundwater As contamination under ambient (reducing) conditions.

Reference for Highlight #1:

Sun, J, Chillrud, S, Mailloux, B, Bostick, BC: In situ magnetite formation and long-term arsenic mobilization under advective flow conditions. Environ Sci Technol 2016, 50(18), pp 10162-10171, DOI:10.1021/acs.est.6202362.

Highlight #2:

Columbia's CEC and RTC publish landmark series on arsenic in U.S. household well water in STOTEN (CEC and RTC)

This year the Columbia SRP CEC and RTC researchers, along with government partners in Maine and New Jersey, published a series of three papers in Science of the Total Environment on arsenic in private well water. The series was based on surveys of private well owners conducted in both states between 2013-2015. Part 1 looks at the impact of the 2002 Private Well Testing Act on testing and treatment behaviors in arsenic-affected areas of New Jersey, Part 2 investigates the effect of town-level testing promotion in New Jersey and its contribution to socioeconomic disparities in testing behavior, while Part 3 explores these patterns of socioeconomic disparity in behavior and their potential impact on arsenic exposure in both New Jersey and Maine. The editors of STOTEN also selected all three papers to be included in a virtual special issue on drinking water contaminants.

References for Highlight #2:
Flanagan, S.V., Spayd, S., Procopio, N., Chillrud, S.N., Braman, S., and Y. Zheng. Arsenic in private well water part 1 of 3: Impact of Private Well Testing Act on household testing and mitigation behavior. Sci Total Environ. 2016; 562:999-1009. PubMed PMID: 27118151; PubMed Central PMCID: PMC5204457.

Flanagan, S.V., Spayd, S., Procopio, N., Chillrud, S.N., Ross, J., Braman, S., and Y. Zheng. Arsenic in private well water part 2 of 3: Who benefits the most from traditional testing promotion? Sci Total Environ. 2016; 562:1010-8. PubMed PMID: 27142115; PubMed Central PMCID: PMC5191845.

Flanagan, S.V., Spayd, S., Procopio, N., Marvinney, R.G., Smith, A.E., Chillrud, S.N., Braman, S., and Y. Zheng. Arsenic in private well water part 3 of 3: Socioeconomic vulnerability to exposure. Sci Total Environ. 2016; 562:1019-30. PubMed PMID: 27118035; PubMed Central PMCID: PMC5204458.

Highlight #3:

Private well arsenic-testing outreach targets pregnant women and children through health care providers (RTC)

Arsenic in drinking water is colorless, odorless and tasteless, so its presence can only be determined by testing. More than 70% of New Jersey's household wells have not been tested for arsenic. Children and unborn babies are populations most at risk of adverse health impacts from arsenic exposure; a high priority is to target well owners serving this group with aggressive testing promotion outreach programs. The Columbia SRP in collaboration with the New Jersey Department of Environmental Protection (NJDEP) and the New Jersey Department of Health (NJDOH) has launched a pilot program in Hunterdon County to offer free drinking water tests for arsenic and lead to patients in ob/gyn and pediatric practices. The overall goal is to determine whether this is an effective approach that should be widely disseminated for reaching these most vulnerable populations. The pilot kicked off with a Grand Rounds talk by Columbia SRP Director Joseph Graziano at the Hunterdon County Medical Center on October 26, 2016 discussing the high prevalence of arsenic in local private wells and risks to unborn babies and children based in part on the Columbia SRP work in Bangladesh and New England. Together with NJDOH and NJDEP, we have created informational brochures and posters for doctors' offices, nurses' work stations and waiting rooms including information on how to take advantage of the free well water testing our labs at Columbia will offer and links for additional information on arsenic treatment options and health effects of arsenic exposure.

TRAINEE HIGHLIGHTS:

- **Anne Bozack** is currently a 3rd year PhD student in Dr. Gamble's laboratory. She is working on studies evaluating the effects of arsenic exposure on DNA methylation using Illumina's 450K and the newer 850K platforms in PBMC samples from arsenic-exposed adults from Dr. Gamble's SRP-related studies.

- **Sara Flanagan** is a public health doctoral student at the City University of New York and a research associate of the Columbia University Superfund Research Program Community Engagement Core. She was a recipient of the 2016 K.C. Donnelly Externship Award. For her externship, Sara is collaborating with the New Jersey Department of Environmental Protection and Department of Health on community engagement and intervention strategies to increase private well arsenic testing and motivate well owners to reduce their risk of exposure. Sara was also the first author of 3 landmark papers published in Science of the Total Environment. (see RTC highlight #2 above).

- **Edwin Ganaprakasam** is in the third year of his thesis and is currently developing methods of characterizing microbial populations using whole genome sequencing. His initial manuscript from his thesis has been submitted (Ganaprakasam et al., submitted) that details the relationship between dissimilatory (respiratory) arsenic reduction, arsenic speciation in the solid phase, and dissolved arsenic concentrations in reducing groundwater systems in Bangladesh.

- **Megan Hall**, Dr. Gamble's former post-doctoral research fellow (currently an Assistant Professor) is co-first author on a manuscript describing the primary findings on Dr. Gamble's FACT study entitled, "Folic acid and creatine supplementation for lowering blood arsenic: A randomized controlled clinical trial" published in Environ Health Persp.

- **Kristin Harper**, Dr. Gamble's former post-doctoral research fellow continues finishing up her analyses of differentially methylated CpGs by arsenic exposure using Illumina's new 450K array and this data was validated by NextGen sequencing (manuscript in preparation). Kristin has also worked on a study of the relationship between arsenic exposure and oxidative stress that has been published. She is currently a Freelance Science Writer and Editor for publications including The Scientist and the American Chemical Society.

- **Ezazul Haque** was a MS trainee in environmental public health wha has been involved in the mobile phone photometry methods (Haque et al. 2017) completed to better measure As concentrations in the field, and to use this data to improve local decision making. He has graduated and moved on to the University of Iowa where he is involved in SRP research with P.I. Larry Robertson.

- **Caitlin Howe** is a former PhD student in Dr. Gamble's laboratory who successfully defended her thesis on May 5, 2016. She had been working on analyses related to our SRP Project #3 in which we are analyzing associations between arsenic exposure and histone modifications as well as on s-adenosylhomocysteine and s-adenosylmethionine and both histone and arsenic methylation; this work has been published in the Journal of Nutrition and in Clinical Epigenetics. Caitlin was invited to speak at the FASEB Summer Research Conference in CO, August 2016. She is currently a post-doc at the University of California (USC) Keck School of Medicine under the mentorship of Drs. Carrie Breton and Shohreh Farzan.

- **Britanny Humann** is a third-PhD student of external collaborator Charles Harvey in the Civil and Environmental Engineering department at MIT. Her field research is supported in part by Project 6 and Cores C and D.

- **Md. Mahfuzur Khan** defended his PhD in Geological Sciences at the University of Delaware in June 2016 under the supervision of external collaborator Holly Michael, who is also supported in part by Project 6 and Cores C and D. He was recently appointed Lecturer in the Geology Department of the University of Dhaka and continues to work with us.

- **Franziska Landes** entered the PhD program in Earth & Environmental Sciences in September 2013, passed the oral exam master's level examination in 2015, her qualifying oral exam in 2016, and continues to be advised by the Project 6 PI.

- **Md. Rajib Mozumder**, a geology graduate from the University of Dhaka, entered the PhD program in Earth & Environmental Sciences in September 2012, passed the master's level examination in 2014,

his qualifying oral examination in 2015, and continues to be advised by the Project 6 PI.

- **Athena Nghiem** is a new PhD student at Columbia University involved in refining and testing remediation efforts at Superfund sites in Massachusetts and North Carolina, as proposed in our future Superfund program. She is currently developing field models for transport at these sites and designing experiments to test injections within existing well fields.

- **Megan Niedzwiecki**, Dr. Gamble's former PhD student, successfully defended her thesis in December 2013. The title of her thesis was, "Mechanisms of Arsenic Toxicity in Humans: Interplay of Arsenic, Glutathione, and DNA Methylation in Bangladeshi Adults." She is currently working as a post-doctoral research scientist working with Dr. Dean Jones at Emory.

- **Gene Pesola** was a doctoral student of Dr. Ahsan's and successfully defended his thesis in 2016 and published two papers related to the HEALS study. (see publications under Project 1)

- **Brandilyn Peters**, Dr. Gamble's PhD student successfully defended her thesis in May 2015. Some of her work involved analyses of differentially methylated CpGs by arsenic exposure and was, along with Kristin (above), instrumental in generating preliminary data for our current SRP Project 3. Brandi is currently a post-doc at New York University.

- **Tiffany Sanchez:** Tiffany successfully defended her thesis in May of 2016. The title of her thesis is "Understanding inorganic arsenic exposure in Bangladesh and respiratory health consequences using a life course approach". She is currently a post-doc at Columbia University working with Dr. Ana Navas-Acien.

- **Roheeni Saxena** is currently a 2nd year PhD student in Dr. Gamble's laboratory. As such, she is completing coursework and writing her qualifying exams. She plans to be involved in Dr. Gamble's new SRP Project related to folate and arsenic metabolism.

- **Jing Sun** completed her PhD at beginning of the grant year and worked as a postdoctoral researcher in the group. During this time, she was active in publishing a number of research papers, most notably Sun et al., (2016), a significant effort to study magnetite-based remediation under conditions akin to those in the field. She was nominated for the Wetterhahn Award to NIEHS for her research and was awarded a graduate student award for exceptional research by the Department of Earth and Environmental Science at Columbia University. She currently has four additional manuscripts in preparation or submitted, and has accepted a postdoctoral research position at the University of Western Australia with a preeminent modeler and will remain a part of our future Superfund program.

- **Kelly Whaley-Martin** is currently completing her PhD at McMaster. She has published a paper in (Waley-Martin et al., (2016) in Environ. Sci. Technol. that establishes that the organic carbon driving microbial respiration in sediments is similar to that in groundwater, and that the carbon that is being most easily metabolized is from surficial environments, even deep within the aquifer. She will attend the University of Toronto on a postdoctoral research fellowship.

PROJECT/CORE PROGRESS UPDATES:

PROJECT 1: A Cohort Study of Health Effects of Arsenic Longitudinal Study: PI – Habibul Ahsan

The association between individual-level arsenic exposure and dermatological, pulmonary, and cardiovascular health outcomes has not been well established in the scientific literature, particularly at low-to-moderate exposure levels. Through our continued follow-up of the HEALS cohort, Jansen et al (2016) evaluated the association of arsenic metabolism phenotypes with participant characteristics and arsenical skin lesions, observing two distinct arsenic metabolism phenotypes uniquely associated with age, sex, body mass index, 10q24.32 genetic variants, and skin lesion status. Metabolism phenotypes include those obtained from principal component (PC) analysis of urinary arsenic species. Two independent PCs were identified: PC1 appeared to represent capacity to produce DMA (second methylation step), and PC2 appeared to represent capacity to convert iAs to MMA (first methylation step). PC2 was positively associated with skin lesion status, while PC1 was not. Furthermore, 10q24.32/AS3MT region polymorphisms were strongly associated with PC1, but not PC2. This work enhances our understanding of arsenic metabolism kinetics and our ongoing effort to unravel toxicity risk profiles. Wu et al (2016) showed that periodontal disease is associated with subclinical atherosclerosis, and Pesola et al (2016) observed an increased risk of heart and lung disease mortality among individuals reporting dyspnea. These endpoints have been previously associated with arsenic exposure and future studies will systematically evaluate interactions with arsenic among individuals with these risk factors.

PROJECT 2. Consequences of Arsenic and Manganese Exposure on Children: PI – Joseph Graziano

Project 2 addresses several questions concerning the health effects of exposure to arsenic and manganese in water (WAs and WMn, respectively) among adolescents. First, does the As-induced respiratory disease observed in adults also manifest itself in adolescents, and what are possible physiologic mechanisms? Second, to what extent do associations between WAs and both lung function brain function reflect the effects of exposure in utero and in infancy, periods of dramatic development for these systems? Third, are WAs and WMn associated with specific cognitive functions in addition to intelligence? We have now completed all of the field work and laboratory analysis in our 725 adolescents (14-17 years old) whose mothers are participants in the HEALS cohort study (Project #1). Based on mothers' well As, measured five times from 2000, we defined four groups with varying levels and patterns of exposure to As: Group 1) consistently low (mean WAs = 3 ppb); Group 2) consistently moderate (mean WAs = 26 ppb); Group 3) consistently high (mean WAs = 146 ppb); and Group 4) high from conception through roughly age one (mean WAs = 201 ppb) but much lower thereafter (mean WAs =13 ppb). Three specific aims target As exposure and pulmonary function (FEV1 and FVC) as well as biomarkers of lung dysfunction in exhaled breath condensate. An additional three aims focus on neuropsychologic outcomes assessed via the Cambridge Neuropsychological Test Automated Battery (CANTAB), and the WISC-IV. Final analyses and manuscripts describing all of these outcomes are in progress.

PROJECT 3: Impact of Nutrition on Arsenic-Induced Epigenetic Dysregulation: PI - Mary V. Gamble

The carcinogenic mechanisms of As are incompletely understood, but emerging evidence suggests that As exposure leads to dysregulation of epigenetic process that can influence gene expression and genomic

stability. In our Bangladesh cohort we have demonstrated that chronic As exposure is associated with increased global DNA methylation, contingent on adequate folate status. We hypothesize that the mechanism underlying this relates to As-induced alterations in histone modifications.

Folate is a key regulator of one-carbon metabolism mediated methylation reactions, including epigenetic modifications such as methylation of DNA and histones. A large randomized trial in Bangladesh has evaluated the effects of folic acid (FA) supplementation on As methylation and blood As concentrations. We conducted a cross-disciplinary collaboration using samples collected from this trial to carry out a set of aims related to nutrition/environment interactions. In these aims, we characterize the influence of As exposure on histone modifications, changes in DNA methylation, and characterized the impact of FA supplementation on these marks (Howe 2016). Finally, we identified a set of genes that are differentially methylated and/or expressed by As exposure. These aims have begun to elucidate the molecular events that underlie the effects of As and folate on DNA methylation. The implications of identifying an influence of FA supplementation on histone modifications and DNA methylation are considerable, as this represents a simple, low-cost, low-risk intervention as a potential therapeutic approach to reverse As-induced epigenetic dysregulation.

PROJECT 4: Arsenic, Iron, Sulfur and Organic Carbon Speciation: PI – Benjamin Bostick

At least 100 million people are exposed to unsafe levels of arsenic (As) in drinking water. Understanding the causes of, and solutions to, this extensive problem, requires detailed characterization of the systems that are affected. This project examines the combination of chemical, biological and physical processes that affect the distribution of As contamination, and how this distribution of As can change in response to human disturbance. Over the last year, we have (1) developed an improved field method for measuring and collecting arsenic concentrations on mobile devices (Haque et al., 2017), and (2) used this method in combination with extensive field sampling to document the heterogeneity and extensive changes in As concentrations in areas subjected to extensive groundwater pumping (Mozumder et al., submitted). We also (3) developed a method of using the radiocarbon signature of the phospholipid fatty acids extracted from sediment samples (Whaley-Martin et al., 2016) to help understand the active biological processes that affect As levels in aquifers. Currently, we are developing parallel efforts to concurrently analyze RNA with DNA to link active microbial populations and metabolisms in aquifers (Gnanaprakasam et al., submitted; Mailloux et al., in prep). Finally (4) we are applying basic research from the above studies to improve our methods of stimulating indigenous autotrophic bacteria to produce magnetite and thereby remediate groundwater with sediments from Dover landfill (Sun et al., 2016). Translation: These efforts offer the potential to improve sustainability and access to safe groundwater, and to remediate Superfund sites much more cost-effectively and rapidly than is practical with current technologies.

PROJECT 5: Application of enhanced mitigation methods for groundwater arsenic at US Superfund sites: PI – Steven Chillrud

Arsenic (As) groundwater contamination is a challenge to remediate at Superfund Sites. We are developing magnetite-based strategies as a new in situ remediation strategy. In the last year, we have begun to (1) to scale up our initial bench-scale experiments examining As contamination; (2) to document the formation of magnetite, and the extent of As removal from groundwater, in open systems (columns) using sediments from the Dover (NH) Superfund site (Sun et al., 2016). Nanoparticulate magnetite forms a diffuse reactive barrier in columns that effectively removes As as groundwater flows through it. (3) We are currently parameterize a biogeochemical model that links the biological processes to mineral transformations and As retention, and scales them up (Sun et al., in prep). Finally (4) we have started to establish the mechanism of magnetite formation and better design groundwater remediation strategies (Jamieson et al. in prep). These results

indicate that autotrophic Fe(II) oxidizers are key to producing magnetite under groundwater conditions typical of As contamination, and that these organisms can be stimulated most effectively by carefully controlling the ratio between iron(II) and nitrate concentrations. Investigator-Driven Translation Efforts: We currently are beginning to design field trials for nitrate-Fe(II) injections in the Lot 84 Superfund Site (Raleigh, NC) and expect the results to be the first direct field-scale test of this method.

PROJECT 6. Defining the Sustainable Uses of Low-Arsenic Aquifers in Bangladesh: PI - Alexander van Geen

Since 2000, the Columbia University Superfund Program has felt the obligation not only to study the mechanisms of arsenic (As) release and transport in groundwater but also to reduce exposure of the 35,000 villagers from Bangladesh participating in the Health Effects of Arsenic Longitudinal Study (HEALS) under Project 1. An inventory of the locations over 900 deep wells installed by the government in the HEALS area led to the conclusion that their allocation was far from optimal and probably favored the local elite. This theme was picked up and amplified by a recent Human Rights Watch report entitled “Nepotism and Neglect: The Failing Response to Arsenic in the Drinking Water of Bangladesh’s Rural Poor” (https://www.hrw.org/news/2016/04/06/bangladesh-20-million-drink-arsenic-laced-water). The issue needs to be addressed as our systematic observations so far show that such deep wells have overwhelmingly remained low in As despite depressurization due to massive municipal pumping for the city of Dhaka that extends to our study area 20-30 km to the east of the capital (Choudhury et al., 2016; Mihajlov et al., 2016; Knappett et al., 2016; Khan et al., 2016). Concerning the fundamental mechanisms of As release to groundwater in shallow aquifers, new results relying on radiocarbon dating of phospholipid fatty acids have confirmed that advected reactive carbon is a major of reductive dissolution of iron oxides (Whaley-Martin et al., 2016). This finding has significant implications for gauging the impact of export of reactive carbon from Superfund sites and landfills in the US.

ADMINISTRATIVE CORE: Co-PIs - Joseph Graziano and Alexander van Geen

Drs. Graziano and van Geen are involved with other SRP investigators in providing mentorship to the many PhD students involved in our research projects, and work with them to guide their preparation of abstracts and presentations at the annual SRP meeting. Indeed, collectively, our PhD students have presented posters and presentations at numerous national meetings, including the annual SRP/FEST meeting, the Society of Toxicology meeting, the International Society of Environmental Epidemiology, the FASEB summer research conference on folate and one carbon metabolism, the Geological Society of American, the American Geophysical Meeting (AGU), the Soil Science Society of American Meeting, the Goldschmidt Conference.
All of our scientific team assembles monthly for a joint two hour meeting which rotates between the Health Sciences Campus and the Lamont-Doherty Earth Observatory Campus. Our monthly meetings often include two hours of seminars, typically one hour for biomedical and one for non-biomedical presentations. We also offer our seminars as webinars which are attended by many outsiders from EPA, NIH, DEP and academia. The seminar series includes a mix of internal and external speakers and has evolved into a world class set of events.
A meeting of our External Advisory Committee (EAC) was held on March 9-10. The committee provided valuable input regarding our specific aims for our most recent competitive renewal application.

CORE A: Data Management Core: PI - Richard Buchsbaum

As no new projects requiring data systems were inaugurated in the past year, the major task of the data management core has been assembling data collected for Projects 1, 2 and 6 and integrating it into the central database. This has in large part been automated through the establishment of a data sharing website. Users with access to primary data collection (questionnaire data entry systems, lab results, clinical test results) can upload these data to the website, where the data files are stored, processed as necessary, and imported into the central database. All data currently being collected, with the exception of the unstructured lab data processed and imported by Ms. Levy, the former core PI who remains in a part-time capacity, is imported via the website. In general, data is updated weekly, though users may upload data as frequently as desired. In addition, the web site provides a file-sharing utility, where data sets and associated files can be uploaded and shared with authorized users.

All data capture and transfer are done according to security protocols established at Columbia University. Data are stored on secure servers; electronic transfers are done over encrypted connections; data are physically moved using encrypted peripheral devices. The entire data system was re-certified by Columbia University Medical Center Information Security in 2015 as suitable for the storage of both research and clinical data.

CORE B. Trace Metals Core Laboratory: PI - Joseph Graziano

The biomedical projects (#1, 2 and 3) of this Superfund Program focus on the adverse health effects of arsenic on the health of adults (#1), adolescents (#2) and on the mechanisms whereby arsenic produces these adverse effects (#3). Naturally occurring arsenic in groundwater used for drinking and cooking is a problem in many regions of the world and in many households in the United States that rely on their own well water. The Trace Metals Core Laboratory enables these three above-mentioned research projects to achieve their objectives by providing a cost-effect central laboratory site that can accurately measure arsenic, arsenic metabolites, and other toxic metals in biological samples derived from the three biomedical research projects. This laboratory participates in numerous quality control programs, national and international, and thus the values obtained for the analysis of blood and urine samples are assured to be accurate.

CORE C. Biogeochemistry Core Laboratory: PI - Alexander van Geen

Over 3000 samples of groundwater, along with about half as many samples analyzed QA/QC purposes (standards, blanks, replicates), were analyzed by high-resolution inductively coupled plasma mass spectrometry for the projects operating in Bangladesh and the US (Projects 1, 2, 3, 4, 5, and 6). With support from Core C, Haque et al. (2016) were able to increase the accuracy of dissolved As measurements with a field-kit by analyzing image of the test strip. The data generated under Core C contributed to several health studies and geoscience studies including those by Stahl et al. (2016), Mihajlov et al. (2016), Choudhury et al. (2016). Core C has also supported the analysis of several hundred sediment samples by XRF-fluorescence for a study of high As levels in paddy soil on rice yield of Huhmann et al. (in review).

CORE D. Hydrogeology Core Laboratory: PI - Peter Schlosser

Detailed knowledge of groundwater flow is essential for understanding geochemical processes in the subsurface. Identification of recharge and discharge areas and mechanisms, as well as flow lines are essential for delineating trends in geochemical evolution, including changes in arsenic concentrations, and to quantify

reaction rates. Depressurization of the deep, low-arsenic aquifer below our study area of Araihazar in Bangladesh by massive pumping for the municipal water supply of Dhaka has been the focus of research supported under Core D. We have shown that the vast majority of 900+ deep community wells installed throughout Araihazar currently provide water that meets the WHO guideline for arsenic in drinking water (Mihajlov et al., 2016; van Geen et al. 2016) but this may not remain the case. Some deep wells can no longer be used by the local population with a simple hand-pump because of the cone depression extending east of Dhaka (Knappett et al., 2016). We have also shown that vertical head gradients resulting from Dhaka pumping could potentially induce downward flow of shallow high-arsenic groundwater (Khan et al., 2016). On the other hand, research conducted with support from Core D demonstrated with leak tests and deployments of a downhole camera that only a small proportion of deep wells in the HEALS area have been improperly installed (Choudhury et al., 2016). Core D also supported the analysis of 30 groundwater samples for tritium and over 1500 samples for the stable isotopes of hydrogen and oxygen.

CORE E. Community Engagement Core: PI - Yan Zheng

The CEC and RTC began a joint collaboration with the New Jersey Departments of Health and Environmental Protection as an academic partner on their 5-year CDC grant to expand work on private well water quality issues in New Jersey. This grant supports new efforts to perform outreach and testing of private wells, developing new methods to increase well testing and treatment, new educational/informational materials highlighting the importance of testing/treatment/maintenance behaviors, and guidance for local health departments to improve services for private well owners. Collaborations during 2016 included development of a pamphlet and poster targeting private well households with pregnant women and small children to be used during planned 2017 clinic-based testing interventions, and the targeted mailing of public health notices offering testing to 2000 addresses in close proximity to a private well with known elevated arsenic. Also in progress is a mailed survey to homes with private wells exceeding the NJ arsenic standard according to Private Well Testing Act records. Analysis of survey responses will identify the psychological, situational, and sociodemographic factors associated with arsenic mitigation and the barriers to protective action faced by this population. Findings will inform development of guidance materials for private well owners managing arsenic contamination and for local health departments to support them in this process. In 2016 CEC and RTC researchers and government co-authors also published a series of 3 papers on arsenic in private well water in Science of the Total Environment, based on their surveys of private well owners in two states.

Research Translation Core (RTC) PIs - Sandra R. Baptista and Steven N. Chillrud

To enhance facilitation of effective communication among SRP scientists, trainees, government partners, and stakeholders the CUSRP Research Translation Core (RTC) established a Twitter account, @Columbia_SRP, to announce our webinars, videos, publications, presentations, and awards, and to follow the activities of the SRP network and partners.

The RTC released its fourth arsenic awareness video, “Arsenic in Well Water: Treatment Options,” along with a set of arsenic treatment Frequently Asked Questions (FAQs). This video was shown at the 2016 EHS FEST Film Festival. The video and FAQs were developed in collaboration with the New Jersey Department of Environmental Protection (NJDEP) and a Barnard Workshop in Sustainable Development and are available on the New Jersey Arsenic Awareness Initiative website. We have improved the website by adding content targeting health care providers to accompany information for private well owners. In partnership with the CUSRP Community Engagement Core (CEC), NJDEP, and New Jersey Department of Health, the RTC developed a clinic-based, health care provider outreach pilot program that offers free arsenic and lead testing

to pediatric and obstetric patients who drink water from private wells in Hunterdon County. CUSRP Director Dr. Joseph Graziano gave a talk for health care providers at the Hunterdon County Medical Center Grand Rounds in October 2016.

The RTC and CEC are collaborating with the Raritan Headwaters Association on research and community well testing programs. The RTC has also initiated collaboration with the Minnesota Department of Health Environmental Health Division and is advising them on surveys of private well owners.

PROJECT/CORE PUBLICATIONS/PRESENTATIONS

Project 1

Publications:

Bulka CM, Davis MA, Karagas MR, Ahsan H, Argos M. The Unintended Consequences of a Gluten-Free Diet. Epidemiology. 2017 Feb 1. doi: 10.1097/EDE.0000000000000640. PMCID: In process.

Yakoob MY, Micha R, Khatibzadeh S, Singh GM, Shi P, Ahsan H, Balakrishna N, Brahmam GN, Chen Y, Afshin A, Fahimi S, Danaei G, Powles JW, Ezzati M, Mozaffarian D; Global Burden of Diseases, Injuries, and Risk Factors: Nutrition and Chronic Diseases Expert Group, and Metabolic Risk Factors of Chronic Diseases Collaborating Group. Impact of Dietary and Metabolic Risk Factors on Cardiovascular and Diabetes Mortality in South Asia: Analysis From the 2010 Global Burden of Disease Study. Am J Public Health. 2016; 106(12):2113-2125. PMCID: PMC5104988.

Wu F, Chen Y, Demmer RT, Parvez F, Paul RR, Shaheen I, Sarwar G, Ahmed A, Eunus M, Ahsan N, Habibullah NM, Islam T, Rundek T, Ahsan H, Desvarieux M. Periodontal diseases and carotid intima-media thickness in Bangladesh. J Clin Periodontol. 2016; 43(11):909-917. PMCID: PMC5063685.

Pesola GR, Argos M, Chinchilli VM, Chen Y, Parvez F, Islam T, Ahmed A, Hasan R, Rakibuz-Zaman M, Ahsan H. Dyspnoea as a predictor of cause-specific heart/lung disease mortality in Bangladesh: a prospective cohort study. J Epidemiol Community Health. 2016; 70(7):689-95.

Jansen RJ, Argos M, Tong L, Li J, Rakibuz-Zaman M, Islam MT, Slavkovich V, Ahmed A, Navas-Acien A, Parvez F, Chen Y, Gamble MV, Graziano JH, Pierce BL, Ahsan H. Determinants and Consequences of Arsenic Metabolism Efficiency among 4,794 Individuals: Demographics, Lifestyle, Genetics, and Toxicity. Cancer Epidemiol Biomarkers Prev. 2016; 25(2):381-90. PMCID: PMC4767610.

McClintock TR, Parvez F, Wu F, Islam T, Ahmed A, Paul RR, Shaheen I, Sarwar G, Rundek T, Demmer RT, Desvarieux M, Ahsan H, Chen Y. 2016. Major dietary patterns and carotid intima-media thickness in Bangladesh. *Pub Hlth Nutr*. **19:**218-229. doi:10.1017/S136898001500124X PMID:25958860

Pesola GR, Forde AT, Ahsan H. Screening for Shortness of Breath: Stretching the Screening Paradigm to Tertiary Prevention. Am J Public Health. 2017 Mar;107(3):386-388. doi: 10.2105/AJPH.2016.303625. PubMed PMID: 28177820.

Oral/poster presentations:

Madhawa Saranadasa (UIC epidemiology predoctoral student), Differential gene expression and chronic arsenic exposure in a transcriptome-wide association study of adults in Bangladesh, Poster presentation at the Superfund Research Program Annual Meeting/EHS Fest, 2016.

Project 2

Publications:

Wasserman GA, Liu X, Parvez F, Factor-Litvak P, Kline J, Siddique AB, Shahriar H, Uddin MN, van Geen A, Mey JL, Balac O, Graziano JH: Child Intelligence and reductions in water arsenic and manganese: A two-year follow-up study in Bangladesh. Environ Health Perspect. 2016 Jul;124(7):1114-20. doi: 10.1289/ehp.1509974. PMCID: PMC4937860

Sanchez TR, Perzanowski M, Graziano JH: Inorganic arsenic and respiratory health, from early life exposure to sex-specific effects: A systematic review. Environ Res. 2016 May;147:537-55. doi: 10.1016/j.envres.2016.02.009. Review. PMCID: PMC4821752

Sanchez TR, Levy D, Siddique AB, Shahriar MH, Uddin MN, Lomax-Luu A, Graziano J, van Geen A, Gamble MV. Provision of well-water treatment units to 600 households in Bangladesh: A longitudinal analysis of urinary arsenic indicates fading utility. Sci Total Environ 2016;563–564:131–7. PMCID: PMC4907796.

Project 3

Publications:

Howe CG, Liu X, Hall MN, Slavkovich V, Ilievski V, Parvez F, Siddique AB, Shahriar H, Uddin N, Islam T, Graziano JH, Costa M, Gamble MV. Associations between blood and urine arsenic concentrations and global levels of post-translational histone modifications in Bangladeshi men and women. Env Health Persp 2016;124(8):1234-40. PMCID: PMC4977054

Hall MN, Howe CG, Liu X, Caudill MA, Malysheva O, Ilievski V, Lomax-Luu AM, Parvez F, Siddique AB, Shahriar H, Uddin MN, Islam T, Graziano JH and Gamble MV. Supplementation with folic acid, but not creatine, increases plasma betaine, decreases plasma dimethylglycine and prevents a decrease in plasma choline in arsenic-exposed Bangladeshi Adults. J Nutr 2016;146(5):1062-7. PMCID: PMC4841924.

Jansen RJ, Argos M, Tong L, Li J, Rakibuz-Zaman M, Islam MT, Slavkovich V, Ahmed A, Navas-Acien A, Parvez F, Chen Y, Gamble MV, Graziano JH, Pierce BL, Ahsan H. Determinants and consequences of arsenic metabolism efficiency among 4,794 individuals: demographics, lifestyle, genetics, and toxicity. Cancer Epidemiol Biomarkers Prev 2016;25(2):389-90. PMCID: PMC4767610.

Howe CG, Gamble MV. Influence of Arsenic on Global Levels of Histone Posttranslational Modifications: a Review of the Literature and Challenges in the Field. Curr Environ Health Rep 2016;3(3):225-37. PMCID: PMC4967376.

Sanchez TR, Levy D, Shahriar MH, Uddin MN, Siddique AB, Graziano JH, Lomax-Luu A, van GA, Gamble MV. Provision of well-water treatment units to 600 households in Bangladesh: A longitudinal analysis of urinary arsenic indicates fading utility. Sci Total Environ 2016;563: 131-137. PMCID: PMC4907796.

Howe CG, Liu X, Hall MN, Ilievski V, Caudill MA, Malysheva O, Lomax-Luu AM, Parvez F, Siddique AB, Shahriar H, Uddin MN, Islam T, Graziano JH, Costa M, Gamble MV. 66. Sex-specific associations between one-carbon metabolism indices and posttranslational histone modifications in arsenic-exposed Bangladeshi adults. Cancer Epidemiol Biomarkers Prev 2016 (E Pub ahead of print).

Howe, CG, Argos M, Farzana J, Parvez F, Rahman M, Rakibuz-Zaman M, Balac O, Baron JA, KibriyaM, Gamble MV and Ahsan H. Sex-Specific Associations between Arsenic Exposure and DNA Methylation and mRNA Expression in Bangladeshi Adults with Arsenicosis. Environ Res (in review)

Oral/Poster Presentations/Conferences Attended in 2016

In April of 2016, Dr. Gamble was invited to give a Seminar at the University of Texas at Austin, Department of Nutritional Sciences. The title of her talk was, “Nutritional Influences on the Metabolism and Toxicity of Arsenic.”

Dr. Gamble was invited to give an oral presentation at the FASEB Summer research conference on Folate, Vitamin B12 and One-carbon Metabolism in Steamboat Springs, CO in August of 2016. The title of her talk was “Folic Acid and Creatine as Therapeutic Approaches to Lower Blood Arsenic: A Randomized, Controlled Trial.”

Dr. Gamble’s recently graduated PhD student, Caitlin Howe, was also invited to give an oral presentation at the FASEB Summer research conference on Folate, Vitamin B12 and One-carbon Metabolism in Steamboat Springs, CO in August of 2016. The title of her talk was, “Sex-Specific Effects of Arsenic on the Methylation and Expression of One-Carbon Metabolism Genes in Bangladeshi Adults with Arsenicosis.”

In November of 2016, Dr. Gamble was invited to speak at the The 8th Princess Chulabhorn International Science Congress entitled, “Environmental Health: Inter-Linkages among the Environment, Chemicals and Infectious Agents” in Bangkok, Thailand. The title of her talk was The title of my talk was “Folic Acid and Creatine as Therapeutic Approaches to Lower Blood Arsenic: A Randomized, Controlled Trial.”

In December 2016, Dr. Gamble attended the SRP Annual Meeting and NIEHS FEST in Durham, N.C. PhD students, Anne Bozack and Roheeni Saxena also attended these back to back meetings.

In November, 2016, Dr. Gamble’s PhD student, Anne Bozack attended a conference entitled, “Epigenetics in Cancer: Translational Medicine Approaches” at the New York Academy of Sciences.

In January 2017, Dr. Gamble’s PhD student, Roheeni Saxena was invited to participate in the 14th Annual APA Environmental Health Scholars Retreat, January 6-8, 2017 in Washington, D.C. She presented her proposal entitled, “Nutritional Influences on Blood Arsenic & Cognitive Function in Children.”

Dr. Gamble served on the Advisory Board of Dr. Maitreyi’s NIEHS Outstanding New Environmental Scientist Award entitled, “Does arsenic increase risk of neural tube defects in a highly exposed population?” The first meeting convened in February of 2016, in Boston, MA.

Project 4

Publications:

Sun J, Steven Chillrud, Brian Mailloux, and Benjamín C. Bostick. 2016. In situ magnetite formation and long-term arsenic immobilization under advective flow conditions.*Environ. Sci. Technol.,* **2016**, 50 (18), pp 10162–10171, DOI: 10.1021/acs.est.6b02362.

Sun J, Benjamín C. Bostick, Brian Mailloux, James Ross, and Steven Chillrud. Use of oxalic acid for mobilizing arsenic from contaminated sediments and decreasing vulnerability to reduction. *J. Hazardous Materials.*, **2016**, 311: 125-133.

Sun J, Andrew Quicksall, Steven Chillrud, Brian Mailloux, and Benjamín C. Bostick. Arsenic mobilization from sediments in microcosms under sulfate reduction. *Chemosphere*, **2016**, 153: 254-261.

Sun J, Chillrud SN, Mailloux BJ, Stute M, Singh R, Dong H, Lepre CJ, Bostick BC. 2016. Enhanced and stabilized arsenic retention in microcosms through the microbial oxidation of ferrous iron by nitrate. Chemosphere. **144:**1106-1115.

Whaley-Martin, K J; Mailloux, B J; van Geen, A; Bostick, B C; Silvern, R F; Kim, C; Ahmed, K M; Choudhury, I; Slater, G F (2016) Stimulation of Microbially Mediated Arsenic Release in Bangladesh Aquifers by Young Carbon Indicated by Radiocarbon Analysis of Sedimentary Bacterial Lipids. *Environ. Sci. Technol.*, 50(14):7353-63. DOI:10.1021/acs.est.6b00868

Ezazul Haque, Brian J. Mailloux, Daisy de Wolff, Sabina Gilioli, Colette Kelly, Ershad Ahmed, Christopher Small, Kazi Matin Ahmed, Alexander van Geen, Benjamin C. Bostick. 2017. Quantitative Drinking Water Arsenic Concentrations in Field Environments Using Mobile Phone Photometry of Field Kits. *Sci. Tot. Environ*.

Myers, Kimberly, Michael. M. Tice, and Benjamin C. Bostick. Submitted. Arsenic(V) in 3,260-million-year-old cherts records a photosynthesis-driven arsenic cycle. *Nature*, In Review.

Brian Mailloux, Tess Kichuk, Khue Nguyen, Benjamin Bostick, Lex van Geen. Coupled radiocarbon and sequencing of RNA indicate that young carbon drives heterotrophic and authotrophic microbial respiration in deep aquifers in Bangladesh. In preparation for *Nature Geosciences*.

Gnanaprakasam E T, J R Lloyd, C Boothman, K M Ahmed, I Chowdhury, B C Bostick, A van Geen, B J Mailloux. Dissecting the association between microbial arsenate reduction and arsenic release in Bangladesh aquifers. Submitted to *Journal of Environmental Microbiology*, December 2016.

K.J. Whaley-Martin, B.C. Bostick, B.J. Mailloux, A. van Geen, K.M. Ahmed, I. Choudhury and G.F. Slater (Submitted) Human and Livestock Waste as a Reduced Carbon Source Contributing to the Release of Arsenic to Shallow Bangladesh Groundwater. Sci. Tot. Environ.

Christine Pries, Kimberly Myers, Brian J. Mailloux, and Benjamin C. Bostick (Submitted) An experimental approach to understanding early post-depositional changes in arsenic and sulfur adsorbed to iron oxides during biologically mediated reduction. *Environ. Chem.*

Jian Xiao, Guanghui Yu, Sen Dou, Benjamin C. Bostick, Yuzhao Tang, Wei, Ran, Song Guan, Qirong Shen, Xi Chen. Novel application of synchrotron-based FTIR technology for the submicron characterization of soil mineral-organic associations. Submitted to *Chemosphere*.

Jian Xiao, Yongli Wen, Sen Dou, Benjamin Bostick, Xi Chen, Yuzhao Tang, Bingjie Chu, Wei Ran, Qi-Rong Shen, Guanghui Yu. Simultaneously visualize and estimate the binding microenvironments between the biopolymers and mineral assemblage in soil microaggregates. Submitted to *Soil Biology and Biochemistry*.

Mozumder M R, C F Harvey, B J Mailloux, B C Bostick, T Ellis, T Chen, E B Sumon, K M Ahmed, A van Geen. Convergence of arsenic concentrations in shallow aquifers of Bangladesh induced by irrigation pumping. In preparation for *Nature Geoscience*.

Khan M.R., H.A. Michael, B. Nath, B.L. Huhmann, C.F. Harvey, A. Mukherjee, M. Chakraborty, I. Choudhury, K.M. Ahmed, S.L. Goodbred, P. Schlosser, B.C. Bostick, B. Mailloux, A. van Geen. Arsenic-rich deep groundwater in the SW Bengal Basin: origin, distribution, and implications for arsenic mitigation. In preparation.

Project 5

Publications:

Sun J, Steven Chillrud, Brian Mailloux, and Benjamín C. Bostick. 2016. In situ magnetite formation and long-term arsenic immobilization under advective flow conditions.*Environ. Sci. Technol.,* **2016**, 50 (18), pp 10162–10171, DOI: 10.1021/acs.est.6b02362.

Sun J, Benjamín C. Bostick, Brian Mailloux, James Ross, and Steven Chillrud. Use of oxalic acid for mobilizing arsenic from contaminated sediments and decreasing vulnerability to reduction. *J. Hazardous Materials.*, **2016**, 311: 125-133.

Sun J, Andrew Quicksall, Steven Chillrud, Brian Mailloux, and Benjamín C. Bostick. Arsenic mobilization from sediments in microcosms under sulfate reduction. *Chemosphere*, **2016**, 153: 254-261.

Sun J, Chillrud SN, Mailloux BJ, Stute M, Singh R, Dong H, Lepre CJ, Bostick BC. 2016. Enhanced and stabilized arsenic retention in microcosms through the microbial oxidation of ferrous iron by nitrate. Chemosphere. **144:**1106-1115.

Christine Pries, Kimberly Myers, Brian J. Mailloux, and Benjamin C. Bostick. Submitted. An experimental approach to understanding early post-depositional changes in arsenic and sulfur adsorbed to iron oxides during biologically mediated reduction. *Environ. Chem.*, Submitted.

James Jamieson, Henning Prommer, Jing Sun, Anna Yusov, Brian J. Mailloux, Steven Chillrud, Benjamin C. Bostick. Rapid precipitation of green rust precursors to magnetite by BoFeN1, a nitrate dependent Fe(II) oxidizer. In Preparation for *Environ. Sci. Technology*.

Anna Yusov, James Jamieson, Henning Prommer, Jing Sun, Brian J. Mailloux, Steven Chillrud, Benjamin C. Bostick. Role of Fe(III) oxides in enhancing As retention in magnetite formed by the autotrophic bacterium BoFeN1. In Preparation for *Environ. Sci. Technology.*

Myers, Kimberly, Michael. M. Tice, and Benjamin C. Bostick. Evidence from rock-records that initial As:Fe ratio and mineralogy affects the extent of As retention under reducing conditions. In Preparation for *Appl. Geochem*istry.

Jing Sun, Brian Mailloux, Steven Chillrud, Alexander van Geen, and Benjamín Bostick. Quantifying ferrihydrite in sediments by the method of standard-additions using EXAFS spectroscopy. Being Revised for *Analytical Chemistry*.

Jing Sun, Henning Prommer, Adam Siade, Steven Chillrud, Brian Mailloux, and Benjamín Bostick. Modeling of iron mineral transformation and arsenic fate under the oxidation of ferrous iron by nitrate. In Preparation for *Environmental Science & Technology*.

Jing Sun, Steven Chillrud, Brian Mailloux, Henning Prommer, and Benjamín Bostick. Mechanisms of arsenic(V) mobilization from iron oxide minerals in the presence of oxalic acid. In Preparation for *Environmental Science & Technology*.

Project 6

Publications:

Pfaff A, Schoenfeld A, Ahmed KM, van Geen A. Reduction in exposure to arsenic limited by insufficient testing and awareness in Bangladesh. Journal of Water, Sanitation and Hygiene for Development, accepted January 2017. NIHMSID 852026

Haque E, BJ Mailloux, D De Wolff, S Gilioli, C Kelly, E Ahmed, C Small, KM Ahmed, A van Geen, BC Bostick. Quantitative drinking water arsenic concentrations measured using mobile phone photometry and field kits. Science of the Total Environment, accepted January 2017. NIHMSID 852033

Khan M.R., Koneshloo M., Knappett P.S.K. Ahmed, K.M., Bostick B.C., Mailloux, B.J., Mozumder R.H., Zahid A., Harvey C.F., van Geen A., Holly A. Michael H.A. Megacity pumping and preferential flow threaten groundwater quality. Nature Communications 7:12833 doi: 10.1038/ncomms12833, 2016. PMID: 27673729.

Whaley-Martin, K; Mailloux, B; van Geen, A; Bostick, B; Silvern, R; Kim, C; Ahmed, K; Choudhury, I; Slater, G. Stimulation of microbially-mediated arsenic release in Bangladesh aquifers by young carbon indicated by radiocarbon analysis of bacterial lipids. Environmental Science and Technology 50, 7353–7363, 2016. PMID: 27333443.

Knappett, PSK, BJ Mailloux, I Choudhury, M Khan, H Michael, S Barua, DR Mondal, M Steckler, H Akter, KM Ahmed, B Bostick, C Harvey, M Shamsudduha, I Mihajlov, R Mozumder, A. van Geen. Vulnerability of low-arsenic aquifers to municipal pumping in Bangladesh. Journal of Hydrology 539, 674–686, 2016. NIHMSID

Sanchez T.R., Levy D., Siddique A.B., Shahriar M.H., Uddin M.N., Lomax-Luu A., Graziano J., van Geen A., Gamble M.V. Provision of well-water treatment units to 600 households in Bangladesh: A longitudinal analysis of urinary arsenic indicates fading utility. Science of the Total Environment 563–564, 131–137, 2016. PMCID: PMC4907796.

Mihajlov I., M. Stute, P. Schlosser, B. J. Mailloux, Y. Zheng, I. Choudhury, K.M. Ahmed, A. van Geen. Recharge of low-arsenic aquifers tapped by community wells in Araihazar, Bangladesh, inferred from

environmental isotopes. Water Resources Research 52, doi:10.1002/2015WR018224, 2016. NIHMSID 852036

Aziz, Z., B. Bostick, Y. Zheng, M.R Huq, M.M. Rahman, K.M. Ahmed, and A. van Geen, Evidence of decoupling between arsenic and phosphate in shallow groundwater of Bangladesh and potential implications, Applied Geochemistry doi:10.1016/j.apgeochem. 2016.03.001, 2016. NIHMSID 747784

Choudhury, I., K.M. Ahmed, M. Hasan, M.R.H. Mozumder, P.S.K. Knappett, T. Ellis, A. van Geen. Evidence for elevated levels of arsenic in public wells of Bangladesh due to improper installation. Groundwater DOI: 10.1111/gwat.12417, 2016. PMCID: PMC5035712

van Geen A, KM Ahmed, EB Ahmed, I Choudhurry, MR Mozumder, BC Bostick, BJ Mailloux. Inequitable allocation of deep community wells for reducing arsenic exposure in Bangladesh. Journal of Water, Sanitation and Hygiene for Development 6, 142-150, 2016. DOI: 10.2166/washdev.2015.115. PMCID: PMC4827352

Barnwal, P, A. van Geen, J. von der Goltz, C.K. Singh. Cost-sharing in environmental health products: evidence from arsenic testing of drinking-water wells in Bihar, India. Revision submitted to Journal of Environmental Economics and Management, January 2017.

Huhmann, B. L., C. F. Harvey, A. Uddin, I. Choudhury, K. M. Ahmed, J. M. Duxbury, B. C. Bostick and A. van Geen. Replacement of arsenic-contaminated soil to restore rice yields in Bangladesh. Submitted to Nature, February 2016.

Whaley-Martin K J, B C Bostick, B J Mailloux, A van Geen, KM Ahmed, I Choudhury, G F Slater, Human and livestock waste as a reduced carbon source contributing to the release of arsenic to shallow Bangladesh groundwater. Submitted Science of the Total Environment, February 2017.

Gnanaprakasamb E T, J R Lloyd, C Boothman, K M Ahmed, I Chowdhury, B C Bostick, A van Geen, B J Mailloux. Dissecting the association between microbial arsenate reduction and arsenic release in Bangladesh aquifers. Submitted to Journal of Environmental Microbiology, December 2016.

Mozumder M R, C F Harvey, B J Mailloux, B C Bostick, T Ellis, T Chen, E B Sumon, K M Ahmed, A van Geen. Convergence of arsenic concentrations in shallow aquifers of Bangladesh induced by irrigation pumping. In preparation.

Khan M.R., H.A. Michael, B. Nath, B.L. Huhmann, C.F. Harvey, A. Mukherjee, M. Chakraborty, I. Choudhury, K.M. Ahmed, S.L. Goodbred, P. Schlosser, B.C. Bostick, B. Mailloux, A. van Geen. Arsenic-rich deep groundwater in the SW Bengal Basin: origin, distribution, and implications for arsenic mitigation. In preparation.

Oral/poster presentations:

1. K.J. Whaley-Martin, A. van Geen, B.C. Bostick, B.J. Mailloux, K.M. Ahmed, I. Choudhury, G.F. Slater. Distinctive Sediment and Adjacent Groundwater Microbial Communities Revealed through Microbial Lipid Distribution and δ13C Analysis. Annual Meeting of the American Geophysical Union, December 2016.

2. Kelly Whaley-Martin, Brian Mailloux, A. van Geen, Benjamin Bostick, Kazi Matin Ahmed, Imtiaz Choudhury & Greg Slater. Sewage Waste Implicated as a Predominant Microbial Carbon Source Mediating Arsenic

Release in Bangladesh Aquifers Through PLFA Δ14C, Sterol Fecal Biomarkers and Cl/Br Ratios. Goldschmidt Conference. Yokohama, Japan, June 26-July 1, 2016.

3. F. Landes and A. van Geen. Developing a field test kit for bioaccessible lead in soil. 1st Annual Urban Soils Symposium: Soils of our City: features and applications at Brooklyn College, Brooklyn, New York, December 9, 2016 (oral).

4. F. Landes and A. van Geen. Developing and deploying a field test kit for bioaccessible lead in soil. Session: T28. Interdisciplinary Approaches to Assessing Environmental Impact of Mining Geological Society of America Annual Meeting in Denver, Colorado. September 26, 2016 (poster).

5. A. van Geen and K.M. Ahmed. Mitigation of the impact of groundwater arsenic on human health and rice yield in Bangladesh: solutions for overcoming the current stagnation. 6th International Congress on Arsenic in the Environment (As2016). June 19-23, 2016 in Stockholm, Sweden (invited keynote).

6. R. Choudhury, C. Mahanta, I. Choudhury, K. M. Ahmed, B. Nath, A. van Geen. Sedimentary controls on arsenic mobilization in groundwater of aquifers in the Brahmaputra River Valley in Assam. 6th International Congress on Arsenic in the Environment (As2016). June 19-23, 2016 in Stockholm, Sweden (oral).

7. A. Farooqi, W. Ali, N. Mushtaq, S. Zahir, A. Younas, T. Ellis, B. Mailloux, A. van Geen. Arsenic exposure in drinking water a growing health threat: well testing in outskirts of Lahore to identify wells low in arsenic to mitigate the As crisis in Pakistan. 6th International Congress on Arsenic in the Environment (As2016). June 19-23, 2016 in Stockholm, Sweden (oral).

8. B. Huhmann, C. F. Harvey, A. Uddin, I. Choudhury, K. M. Ahmed, J. M. Duxbury, B. C. Bostick, A. van Geen. Replacement of arsenic-contaminated soil for improved rice yields in Bangladesh. 6th International Congress on Arsenic in the Environment (As2016). June 19-23, 2016 in Stockholm, Sweden (oral).

9. A. van Geen. Mitigation of the impact of groundwater arsenic on human health and rice yield in Bangladesh: solutions for overcoming the current stagnation. University of Vermont, February 2016 (invited).

10. A. van Geen and K.M. Ahmed. Mitigating the Impact on Human Health of Groundwater Contamination with Arsenic in Bangladesh: Overcoming the Current Stagnation. Annual Meeting of the Allied Social Sciences Associations (ASSA). Chicago January 6-8, 2017 (invited).

Cores A-D

There are no unique core specific publications from these cores but the publications from the projects above heavily rely on their contributions.

Core E

Publications:

Flanagan, S.V., Spayd, S., Procopio, N., Chillrud, S.N., Braman, S., and Y. Zheng. Arsenic in private well water part 1 of 3: Impact of Private Well Testing Act on household testing and mitigation behavior. Sci Total Environ. 2016; 562:999-1009. PubMed PMID: 27118151; PubMed Central PMCID: PMC5204457.

Flanagan, S.V., Spayd, S., Procopio, N., Chillrud, S.N., Ross, J., Braman, S., and Y. Zheng. Arsenic in private well water part 2 of 3: Who benefits the most from traditional testing promotion? Sci Total Environ. 2016; 562:1010-8. PubMed PMID: 27142115; PubMed Central PMCID: PMC5191845.

Flanagan, S.V., Spayd, S., Procopio, N., Marvinney, R.G., Smith, A.E., Chillrud, S.N., Braman, S., and Y. Zheng. Arsenic in private well water part 3 of 3: Socioeconomic vulnerability to exposure. Sci Total Environ. 2016; 562:1019-30. PubMed PMID: 27118035; PubMed Central PMCID: PMC5204458.

Flanagan, S.V. and Y. Zheng. The case for universal screening of private well water quality in the U.S. and testing requirements to achieve it: Evidence from arsenic. Environmental Health Perspectives, In Press.

Oral/Poster Presentations:

Zheng, Y. The case for universal screening of private well water quality in the U.S. Evidence from Arsenic. Risk e-Learning Webinar, SRP Water Innovation: Session IV – Communicating Risk and Engaging Communities: Arsenic and Well Testing, July 21, 2016.

Flanagan, S.V. Arsenic in private well water: Socioeconomic vulnerability to exposure in Maine and New Jersey. Webinar, CDC Private Well Community of Practice. September 21, 2016.
Zheng, Y. The case for universal screening of private well water quality in the U.S.: Evidence from arsenic. Civil and Environmental Engineering Seminar, Madison, WI, November 2016

Flanagan, S.V., Spayd, S., Procopio, N., Chillrud, S., Braman, S., Ross, J., and Y. Zheng. Reducing exposure to arsenic from private well water: Who benefits most from traditional testing promotion? Poster presented at EHS-FEST, Durham, NC, December 2016.

Zheng, Y. and S.V. Flanagan. The case for universal screening of private well water quality in the U.S.: Evidence from arsenic. Poster presented at EHS-FEST, Durham, NC, December 2016.

RTC

Publications:

Flanagan, S.V., Spayd, S.E., Procopio, N.A., Chillrud, S.N., Braman, S., Zheng, Y. Arsenic in private well water part 1 of 3: Impact of the New Jersey Private Well Testing Act on household testing and mitigation behavior. *Science of the Total Environment*. 2016 August 15; 562:999–1009. Epub 2016 April 23 PMID: 27118151 PMCID: PMC5204457 doi: 10.1016/j.scitotenv.2016.03.196

Flanagan, S.V., Spayd, S.E., Procopio, N.A., Chillrud, S.N., Ross, J., Braman, S., Zheng, Y. Arsenic in private well water part 2 of 3: Who benefits the most from traditional testing promotion? *Science of the Total Environment.* 2016 August 15; 562:1010–1018. Epub 2016 April 30 PMID: 27142115 PMCID: PMC5191845 doi: 10.1016/j.scitotenv.2016.03.199

Flanagan, S.V., Spayd, S.E., Procopio, N.A., Marvinney, R.G., Smith, A.E., Chillrud, S.N., Braman, S., Zheng, Y. Arsenic in private well water part 3 of 3: Socioeconomic vulnerability to exposure in Maine and New Jersey. *Science of the Total Environment.* 2016 August 15; 562:1019–1030. Epub 2016 April 23 PMID: 27118035 PMCID: PMC5204458 doi: 10.1016/j.scitotenv.2016.03.217

Oral/poster presentations:

Graziano, J. “Exposure, Consequences and Treatment of Lead Poisoning” and presentation to the pediatric residents on the adverse effects of arsenic in children. Presentations at the Pediatric Grand Rounds seminar, University of Michigan in Ann Arbor, June 21, 2016.

Zheng, Y. The Case for Universal Screening of Private Well Water Quality in the U.S.: Evidence from Arsenic. Webinar presentation for the NIEHS SRP fourth session in the Risk e-Learning webinar series *SRP Water Innovation - An Integrated Approach to Sustainable Solutions. Session IV, Communicating Risk and Engaging Communities: Arsenic and Well Testing*, July 21, 2016.

Flanagan, S.V., Arsenic in Private Well Water: Socioeconomic Vulnerability to Exposure in Maine and New Jersey. Webinar presentation for the Private Well Community of Practice Webinar, CDC's Division of Environmental Hazards and Health Effects, September 21, 2016.

Graziano, J. Poison in the well: Acting on health risks to parents, newborns and children exposed to elevated well water arsenic in Hunterdon County, New Jersey. Presentation at the Hunterdon County Medical Center Grand Rounds, Raritan Township, New Jersey, October 26, 2016.

Flanagan, S.V., Spayd, S.E., Procopio, N.A., **Chillrud, S.N.**, **Braman, S.**, **Ross, J.**, Marvinney, R.G., Smith, A.E., **Zheng, Y.** Reducing exposure to arsenic from private well water: Who benefits most from traditional testing promotion? Poster presented at the SRP Annual Meeting, Durham, North Carolina, December 5, 2016.

Baptista, S.R., **Carcone, J.**, **Chai-Onn, T.**, **Gerard, A.**, **MacManus, K.**, **Yetman, G**. National Priorities List (NPL) Superfund Footprint: Site, Population, and Environmental Characteristics Mapper. Presentation at the EHS FEST Sensors and Technologies Fair, Durham, North Carolina, December 6, 2016.

Chillrud, S.N., Blair, J., **Yan, B.**, **Perzanowski, M**. Modular Monitors for Particulates, Black Carbon, PAHs/VOCs and Bioaerosols for Public Health Studies. Presentation at the EHS FEST Sensors and Technologies Fair, Durham, North Carolina, December 7, 2016.

CUSRP Monthly Seminars/Webinars: (Video recordings are available on the CUSRP YouTube Channel)
September 19, 2016
Andrew E. Smith, S.M., Sc.D., State Toxicologist and Director of Environmental and Occupational Health Programs, Maine Center for Disease Control and Prevention, Maine Department of Health and Human Services: **Everything but the Kitchen Sink: Efforts to Reduce Exposure to Arsenic from Well Water in Maine**.

Brittany Huhmann, M.S., Ph.D. Student, Department of Civil and Environmental Engineering, National Science Foundation Graduate Research Fellow, Massachusetts Institute of Technology: ***Impact of Soil Arsenic on Rice Yields in Bangladesh***.

October 17, 2016
Habibul Ahsan, M.D., Louis Block Professor of Epidemiology, Medicine & Human Genetics and Director, Center for Epidemiology & Prevention, University of Chicago: **Bangladesh Vitamin E and Selenium Trial: Preliminary Results and Lessons Learned**.

Nicholas A. Procopio, Ph.D., GISP, Bureau Chief, Division of Science, Research, and Environmental Health, New Jersey Department of Environmental Protection: **New Jersey's Private Well Testing Act and Geographic Summary of Over a Decade of Data**.

November 30, 2016
Ana Navas-Acien, M.D., M.P.H., Ph.D., Professor of Environmental Health Sciences, Mailman School of Public Health, Columbia University: **Epidemiologic Research on Arsenic at Low Exposure Levels: Exposure Assessment Challenges and Possible Solutions**.

Mason Stahl, Ph.D., recent graduate of the Department of Civil and Environmental Engineering, Massachusetts Institute of Technology: **Organic Carbon Dynamics and Redox Changes in an Arsenic Contaminated Aquifer in Bangladesh**.

January 30, 2017
Koren K. Mann, Ph.D., Senior Investigator, Lady Davis Institute for Medical Research and Associate Professor, Department of Oncology, McGill University: **The Contribution of Arsenic 3 Methyltransferase in Arsenic-enhanced Atherosclerosis.**

Other presentations/publications of interest:

Human Rights Watch Report. *Nepotism and Neglect: The Failing Response to Arsenic in the Drinking Water of Bangladesh's Rural Poor* (April 6, 2016) https://www.hrw.org/report/2016/04/06/nepotism-and-neglect/failing-response-arsenic-drinking-water-bangladeshs-rural was informed by a research study conducted in Araihazar by CUSRP scientists: A. van Geen, K.M. Ahmed, E.B. Ahmed, I. Choudhurry, M.R. Mozumder, B.C. Bostick, and B.J. Mailloux, "Inequitable Allocation of Deep Community Wells for Reducing Arsenic Exposure in Bangladesh," *Journal of Water Sanitation and Hygiene for Development,* 2016 March 1; 6(1):142–150. PMID 27087915 PMCID PMC4827352 doi: **10.2166/washdev.2015.115**

Funkhouser, D. *Get the Facts: Arsenic in New Jersey Well Water*. Columbia University, Earth Institute State of the Planet blog, June 16, 2016. http://blogs.ei.columbia.edu/2016/06/16/get-the-facts-arsenic-in-new-jersey-well-water

Braman, S. and Flanagan, S.V. Water Pump Race and "What's in Your Drinking Water?" Exhibits presented at the Lamont-Doherty Earth Observatory Open House, Columbia University, Palisades, NY on October 8, 2016. CUSRP had exhibits on water use and the challenges of collecting safe water in Bangladesh as well as on drinking water quality issues for users of private well water and public tap water in the U.S. We also distributed about a dozen test kits to people interested in testing their water through our lab. Volunteer Barnard College students who helped with the exhibits were: Giulia Gandolfo, Kim Myers, Michelle Lee and Afsana Akter. Other exhibit volunteers included: Athena Nghiem and Franziska Christine Landes (both Ph.D. students in the Earth and Environmental Science program at Columbia University) and Tyler Ellis (Senior Research Staff Assistant in Geochemistry at the Lamont-Doherty Earth Observatory).

Grant, T. Shining a Spotlight on the Environment: Research Center Reaches a Wider Audience by Contributing Data to the Living Atlas of the World. ArcWatch: GIS News, Views, and Insights. December 2016. http://www.esri.com/esri-news/arcwatch/1216/shining-a-spotlight-on-the-environment
This article highlights the Center for International Earth Science Information Network's (CIESIN's) contributions to Esri's Living Atlas of the World, including the *ATSDR Hazardous Waste Sites on National Priorities List (NPL)*. It provides links to a Living Atlas Story Map at http://arcg.is/29C5w9t and the ATSDR Hazardous Waste Sites on NPL georeferenced data layer available via ArcGIS Online at http://arcg.is/2jnkqBN.

Website URLs:

Columbia SRP Program website: http://superfund.ciesin.columbia.edu
New Jersey Arsenic Awareness Initiative website: http://njarsenic.superfund.ciesin.columbia.edu
Columbia SRP YouTube channel: https://www.youtube.com/channel/UCI1Ruh5VQLdvEjZsvBxUIFQ