

2014-06-03 15.01 Part 4_ Prevention and Remediation Strategies for Arsenic Exposure

Danielle Carlin: Well, welcome, everybody, to the fourth and final webinar in the Health Effects and Mitigation of Arsenic: Current Research Efforts and Future Directions workshop panel discussion series. My name is Dr. Danielle Carlin, and I am one of the Program Administrators with the Superfund Research Program at the National Institute of Environmental Health Sciences, also known as NIEHS.

So the NIEHS Superfund Research Program, or SRP, is hosting this series of four expert panel discussions that will focus on the current state of knowledge and data gaps in the field of arsenic environmental health research. Topics include exposure sources and mitigation, remediation, bioavailability, contributions of advanced techniques and susceptibility.

These panel discussions stem from the workshop that was held in Research Triangle Park, North Carolina, on March 3 and 4, 2014. The panel discussions, originally scheduled to be held at that workshop, unfortunately were postponed due to inclement weather. This webinar is the last in the series, and it is titled Prevention and Remediation Strategies for Arsenic Exposure.

We invited leading researchers to serve as panelists to support discussions on specific questions, and you will hear more about the webinar format from our session moderator, who is Dr. Heather Henry, shortly. We are grateful to the session moderator and the panelists for their time and effort in this webinar.

So, the goal of these panel discussions is to highlight new techniques and identify data gaps to help guide future research directions. The panelists each propose answers to specific questions posed to them, and panelists will discuss their answers towards the goal of a consensus answer.

We encourage you, the audience, to submit your written questions and comments during the webinar, as well, and the moderator will tell you more about the format of this webinar discussion. Information from the workshop and from this webinar series will be captured in a report that is being written by Dr. Marisa Naujokas from MDB, Inc.

So the session moderator for today's webinar is Dr. Heather Henry, and she is a Health Scientist Administrator, also with the Superfund Research Program, within the Hazardous Substances Research Branch at the NIEHS. And I would like to personally say thank you, Heather, for moderating this session, and now I'm going to turn it over to you.

Heather Henry: Thank you, Danielle. It's my pleasure to be here today, and looking forward to hearing today's discussion about prevention and remediation strategies for arsenic exposure. At the end of today's discussion we would like to have consensus answers to these questions. Answers can be lists or descriptions of major points, techniques, concerns or concepts. Although consolidating complex information can be difficult, it challenges us to discern the most important points relevant to the questions.

So we will be following a strict time schedule, as shown in this slide. If time allows, we can revisit questions that might benefit from additional discussion toward the end of the webinar.

Danielle will mark time at 13 minutes into the discussion, which will promptly end at 15 minutes.

Panelists were each tasked with a specific question. The lead panelist for each question proposed an answer as a starting point for discussion. We can add to or change the proposed answer, and from this discussion we hope to capture data gaps in order to guide future research.

Moderators and panelists will participate verbally in the webinar. Other participants in the webinar are muted by the webinar technical staff, but you are welcome to submit written comments using the panel on the right side of your screen. We will include them as time allows. NIEHS will collect all written questions and comments for the consideration in the final report.

So I will briefly review the questions and the panelists for today's session.

Our first question is nutrition is a preventative strategy that can reduce the adverse health effects of arsenic exposure. What are the considerations, limitations and challenges to using this approach? What are some of the other more recent nutritional interventions that we should be aware of?

And our panelists for this question are Mary Gamble, Ph.D., who is the Associate Professor of Environmental Health Sciences at Columbia University. She is joined with Megan Hall, also Ph.D., who is an Assistant Professor of Epidemiology at Columbia University.

Moving on to our second question, how can communities be made aware of potential exposure to arsenic and opportunities for prevention? Should blanket testing of private wells for arsenic throughout the United States be offered or imposed?

Our panelist for this question also comes to us from Columbia University, Alexander Van Geen, who's a Ph.D. and the Doherty Senior Research Scientist at the Lamont-Doherty Earth Observation, and, again, he is the Associate Director of the Earth Clinic at Columbia University.

For our third question, what are the biggest challenges and opportunities for preventing arsenic exposures? What types of prevention and remediation options are needed considering each exposure route and each media?

Our panelist for this question is Dr. Julie Zimmerman. She's an Associate Professor jointly appointed to the Department of Chemical Engineering, Environmental Engineering Program and the School of Forestry and Environment at Yale University.

And our fourth question is arsenic is an interesting toxicant because much of the exposure occurs from natural sources. What exposures occur due to anthropogenic processing, such as mining? How can these exposures be evaluated? What types of prevention strategies are there to minimize arsenic exposures from anthropogenic sources, such as Garden Roots Project?

Our panelist for this question is Dr. Raina Maier. She's Professor of Environmental Microbiology in the Department of Soil, Water and Environmental Sciences and Director of the University of Arizona NIEHS Superfund Research Program.

So we can proceed now to the first question about nutrition, and at this time I would like to pass it off to Mary and Megan.

Mary Gamble: Thanks, Heather. Good afternoon and welcome. I'd like to start by thanking our colleagues at NIEHS for organizing this webinar series and for inviting us to participate in it.

So, as Heather has indicated, we were charged with the following questions. Nutrition is a preventative strategy that can reduce the adverse health effects of arsenic exposure. What are the considerations, limitations and challenges to using this approach? What are some of the other more recent nutritional interventions that we should be aware of? So I will start by addressing the considerations section, largely within the context of our work on folate, and then Megan Hall is going to talk about the limitations and challenges and will speak a bit more broadly.

So, in general, nutritional interventions represent low-cost, low-risk options that have much broader implications, even beyond arsenic, particularly in countries where nutritional deficiencies are common. Consider that the 10 countries with the most significant known problems of environmental arsenic exposure, including Bangladesh, Cambodia, Thailand, Vietnam and others, these 10 countries collectively represent roughly 45 percent of the world's population and a very high portion of the global burden of arsenic-related.

Most of these are low- and middle-income countries in which nutritional deficiencies are common. None of these countries currently have, for example folate fortification programs, unlike much of the rest of the world, and many have known problems of multiple micronutrient deficiencies. So the implications are quite broad.

The study population: It's important to know what are the nutritional deficiencies or limitations in your study population. Typically nutritional interventions are more likely to be effective if the nutrient or micronutrient in the study population is limiting to begin with.

Age range: Are you studying children or adults? This is important, because the tendency for deficiency differs by age and by nutrient. For example, children are much more likely to be deficient in vitamin A than adults, because they haven't yet accumulated stores, and yet they're less likely to be deficient in folate, for reasons that are not understood. In addition, many metabolic parameters, such as folate metabolism, differ vastly by age.

Studies of pregnant women are important because they represent critical windows of susceptibility. At the same time, nutritional status undergoes wide fluctuations as a result of being pregnant. Choline biosynthesis is hugely upregulated, while at the same time moms preferentially deliver folate to the fetus, even at her own expense. So plasma folate levels are a moving target during pregnancy. Pregnant women are also more likely to be taking prenatal nutritional supplements.

Next, nutritional interventions that are most likely to be successful take into consideration our understanding of the underlying physiology of arsenic metabolism and mechanisms of toxicity. For example, we know that arsenic undergoes hepatic methylation, generating mono and dimethyl arsenical species, illustrated as MMA and DMA here. And the monomethyl form is more toxic, but the dimethyl form has a much shorter circulating half-life and is rapidly excreted in urine.

The effect of methyl donor depletion on arsenic metabolism was first shown in studies in mice and in rabbits in the mid-1980s, and that formed the basis of our folate studies in Bangladesh. More recently, work by David Thomas and Sam Cohen's groups illustrates that mice deficient in arsenic methyltransferase accumulate a burden -- a body burden of arsenic that's many times greater than wild-type mice, resulting in rapid and systemic arsenic toxicity.

So the methyl donor for these reactions is S-adenosylmethionine, or SAM, and SAM biosynthesis relies largely but not exclusively on folate. Based on this underlying biochemistry, we've shown in a randomized, controlled clinical trial that folate supplementation increases arsenic methylation and lowered total blood arsenic on average by 14 percent and lowered blood MMA by 22 percent.

Next slide. So, prevention is a key word here. It should not be confused with treatment. For example, our folate findings should not be taken to suggest that folate supplementation should be used as a treatment for people with, for example, arsenic-induced blood or lung cancer. Keep in mind that rapidly dividing cells such as cancer cells require folate for nucleotide biosynthesis and for survival. While folate is protective against cancer in the general population, the question of whether or not folate could potentially accelerate cancer progression in individuals having preexisting cancerous lesions is somewhat debatable.

Dose should also be taken into consideration. Some micronutrients, for example, niacin, take on pharmacological properties at high doses. It's a common myth that micronutrients are benign at all doses.

Work from Allan Smith and Craig Steinmaus in Chile and other work in Taiwan clearly demonstrates that increased risk for arsenic-related diseases persists long after arsenic exposure is reduced. So there's a need to identify and implement intervention strategies for arsenic-exposed at-risk populations even after exposure is reduced.

Next, folate, choline and betaine are dietary methyl donors that are important in many, many methylation reactions. There are over 100 known methyltransferase enzymes and substrates that undergo methylation. Their kinetics vary widely. For arsenic methyltransferase, published values vary by experimental conditions. DNA methyltransferases have very low K_m 's for SAM, and, contrary to popular belief, folate is really only very weakly correlated with global DNA methylation. But we have found that folate and possibly other micronutrients can modify the effect of arsenic on DNA methylation. In other words, the ability of arsenic to interfere with DNA methylation may depend on the availability of methyl groups derived ultimately from folate.

Okay, so now I'm going to pass the baton to my colleague Megan Hall, who will address the challenges and limitations as well as some other interventions. Megan?

Megan Hall: Okay, great. Thank you, Mary. Can everybody hear me okay?

Heather Henry: Yes, you sound great. Thanks, Megan.

Megan Hall: Okay, great. Okay, so I think Mary and I would both like to emphasize first that we believe that reduction in arsenic exposure through remediation should always be the first priority. And I know that Lex will talk more about this. And we see nutrition as being a complementary, another approach that might be used to reduce arsenic-associated adverse health effects.

One of the challenges in studying nutrition in relation to arsenic toxicity is that not all nutrients will necessarily behave in the manner in which you predict they will, particularly when you're studying the nutrients involved in a complex metabolic pathway such as one-carbon metabolism, which is the pathway involved in arsenic methylation. So, as an example of this, we have found that glutathione is associated with increased arsenic methylation in an observational study. But it's unclear whether supplementation with cysteine, which is involved in the synthesis of glutathione, will increase arsenic methylation to DMA and facilitate excretion, or maybe it will increase the reduction of the pentavalent to the trivalent arsenical species, potentially increasing toxicity. And the answer to that question is not obvious based on solely -- based on what we know about the biochemistry.

One approach that we've tried to use to tease this apart a little more is mathematical modeling of arsenic methylation in collaboration with two investigators at Duke University. We see that as a tool that can be used in combination with our observational epidemiology studies and with experimental data to explore possible outcomes prior to any type of intervention.

Another factor to take into consideration is that there is measurement error in essentially every study that's conducted. So all studies involve some degree of measurement error. And this introduces noise into your findings, and if that noise is completely random with respect to your exposure and your outcome, then your findings can be attenuated towards the null, and that is particularly true for observational studies.

And so, as an example, in Mary's first cross-sectional study she found associations between plasma folate status and urinary arsenic methylation profiles that were statistically significant but fairly weak. Nevertheless, she followed that up with a folate intervention study and found that, as she mentioned, folate supplementation increased arsenic methylation quite substantially and lowered blood arsenic and blood MMA by substantial amounts.

I think that diet studies, continuing with the line of talking about measurement error, I think that studies that use measurements of dietary intake by questionnaire are often criticized, sometimes with good reason and sometimes not. And I think that in particular for those studies there are a number of points to consider.

And these studies can have great utility and provide some insight as to potential micronutrients that might be suitable for intervention studies, and an example of that is dietary protein intake. Pretty consistently across the board studies that have looked at dietary protein intake in relation to arsenic methylation have shown that it is favorably associated with arsenic methylation.

I think an important factor to consider in studies using, for example, food frequency questionnaires, is that the validity and the reproducibility of the diet questionnaire in the population under study should really be examined before it's put to use. That's not something that's always done. People oftentimes adapt a questionnaire that was used in another study and don't go through the steps of sort of validating that questionnaire in their study population.

There can often be in these studies the issue of multiple comparisons. Sometimes investigators will calculate dietary intakes of several nutrients and look at those nutrients in relation to their outcome, and you can quickly run into the problem of having statistically significant findings that are due to chance alone.

Another issue to consider is the adjustment for total energy intake, which is sort of a very important issue in the field of nutritional epidemiology. And anyone who's considering using a dietary questionnaire should sort of look into the different approaches that are available to adjust for that in their statistical analysis.

And I think ultimately the utility of, for example, food frequency questionnaires, is very nutrient specific and population specific. An example, coming back to folate, in Bangladesh is that folate intake from a food frequency questionnaire in our study population is not a very good indicator of plasma folate because folate in food is very susceptible to oxidative degradation during prolonged cooking, which is a very common -- which is very common in Bangladesh traditional methods of food preparation. There might be other nutrients in our population which can be captured very well using a food frequency questionnaire.

Okay, next slide, please. An additional limitation to consider is that mechanistic studies in humans are obviously critically essential, but they're limited to accessible cells and tissues. For example, epigenetic studies are restricted to measuring cells and DNA derived from blood, and in the case of arsenic exposure there's good evidence that bone marrow progenitor cells are a target tissue of arsenic. So, while the use of PBMCs may not be appropriate for all environmental exposures, they're actually a very good cellular target for study in the case of arsenic exposure. People often ask why we don't get other types of tissue samples in our study population, and the answer is that it's simply not feasible to do that in the setting of an epidemiologic study.

Danielle Carlin: Megan, we have two more minutes.

Megan Hall: Okay, thank you. And then in thinking about inference, and I think that this is a really important point, lowering, for example, blood arsenic concentrations with folic acid supplementation, it's logical that that should lower risk by inference, but inference is not the same as proving prevention. And that would require large, long-term clinical trials that are, unfortunately, very costly and don't provide answers for a very long period of time.

We've tried to sort of get around this by using some other study designs that allow us to look at these associations in a prospective manner, so where the exposure clearly occurs before the outcome. One approach that we've used to do that is a nested case control study design. And, for example, using that design we showed that folate deficiency, hyperhomocysteinemia and hypomethylation of DNA were associated with subsequent risk for arsenic-induced skin lesions. But that is still not the same as demonstrating that a nutritional intervention will prevent adverse health effects from arsenic exposure.

And then the last point is in scaling up micronutrient interventions it's important to think about, of course, who your target population is. Would it be only deficient individuals, entire populations? Food fortification programs have been very effective in some countries, and that's a great way of reaching a very broad target population. But this is often very difficult to do in low- and middle-income countries where foods are often produced locally. And this can introduce challenges related to quality control.

And then just very quickly we have some ongoing studies of nutritional interventions that we just wanted to mention. Mary's working on a folic acid and creatine intervention trial in a random sample of the population in our study area in Bangladesh. The outcome -- main outcome is total blood arsenic concentration. Habib Ahsan has a vitamin E and selenium trial in individuals in Bangladesh with skin lesions. And I've done some work on a pilot study of supplementation with two other nutrients, choline and betaine, with the outcome of arsenic methylation.

And then the last slide, the next slide, please, so the point of this slide is just to illustrate that the nutritional influences on one-carbon metabolism and therefore methylation are many and they are complex. So every intermediate shown in red on this slide is a micronutrient that can potentially influence the methylation of arsenic and other substrates.

With that, thank you for your attention, and if there's time we'd be happy to take any questions. Thank you.

Danielle Carlin: Thank you very much, Megan and Mary. I think for the sake of time we'll move on to our next set of questions, but we do encourage anyone listening as well as our other panelists to think about questions and reflect on the points that you've made so we can make those thoughts part of the discussion at the end.

So at this point I will pass it off to Alexander Van Geen.

Alexander Van Geen: Yes, good afternoon. Thank you. So, I will try to address two questions. First one is, as you read, how can communities be made aware of potential exposure to arsenic and opportunities for prevention?

I should say from the onset that I've concerned myself mostly with arsenic mitigation and exposure reduction in Bangladesh, but fortunately the Columbia SRP includes a component of mitigation in both Maine and New Jersey, and this takes place under our Research Translation Core, led by Steve Chillrud and Meredith Golden, and our Community Engagement Core, which

is led by Yan Zheng. And so what I'm going to try to do over the next couple of slides is essentially to relay information that I've obtained through them and by interacting with them.

So, let's -- and my understanding is that this question was restricted to the US population, so that's what I will be talking about. So in order to scale the problem I think it's useful to go back to some basic statistics that many of you have seen. And the striking one, to me, at least, every time is that 15 percent of the US population, that's on the order of 43 million people, still relies on private wells throughout the country, obviously mostly in rural areas, and that is the source of water used for drinking and cooking, and many wells -- of these wells are untested, and we'll come back to that.

Now, the testing that has been done across the country in a systematic fashion suggests that perhaps on the order of 3 million people today are drinking water that doesn't meet the WHO guideline for arsenic of 10 mcg/liter. So it's a very significant number. I mean, it's an order of magnitude lower than the population exposed to those levels in Bangladesh and neighboring countries, but it's still clearly a very large number.

And I'm not going to address sort of another 2 million people, which is the current population believed to be drinking water from a public water system that as of 2011 was not meeting the WHO guideline, which became the US maximum contaminant level and EPA level in 2001. So that's -- there's a sizable number of people there, but I won't address that. I think what I should focus is on the 3 million people who are drinking their water from private wells.

And from my limited experience I understand that this is where county health departments, of which there are many all over the country, that they are probably the organization that is most closely involved. And what my colleagues have tried -- are doing now both in Maine and in New Jersey is essentially mailing flyers that explain the risk of exposure to arsenic and encourage well owners to send a sample of their water to testers, to reputable testers, by providing them with a list of laboratories, and at the same time, if the news is bad, also inform the well owners that there are some methods to treat the water at the individual household level, and those include reverse osmosis, there is iron-based adsorption media. I think we'll hear about that more later.

I should point out, though, that in a sizable survey carried out by Yan Zheng and her Ph.D. student Sara Flanagan, it turns out that it was a bit of a convenient sample. These were people who responded to flyers sent out by the group. But 15 percent of these treatment systems in Maine were found to fail. So they were not providing water that contained less than 10 mcg/liter arsenic. Some of that is maintenance. There may be other causes. Some matrices are more difficult to treat. But clearly the -- how well the treatment system works should be checked on a regular basis in areas where private wells are likely to be high in arsenic.

Now, something that I think is still maybe a little bit more controversial right now, which sort of and in a way gets closer to my own experience in Bangladesh, laboratories are great, but it takes some effort to send a sample. It costs several tens of dollars. From -- in a way, and I'm putting a question mark next to this, one might want to encourage well owners to test their own well.

There is one particular field kit that we use extensively in Bangladesh. We have just finished testing about 50,000 wells in our study area with that, and we've collected quality control samples with that. And it happens to be made by a US company, and you can buy a sort of small version of that kit, you can buy it on Amazon. So that's what I listed there. I don't have any financial interest in this company, if anyone is worried about that. We found that this kit really works remarkably well over a wide range of conditions.

There are a couple of concerns, and this has affected the way it was deployed in Maine, according to Yan Zheng. One of them is that the kit generates arsine, which is one of the most toxic forms of arsenic if you breathe it, obviously, and so the kit instructions stress the fact that the water needs to be tested outside in a well-ventilated area.

And the other one is that the little strips that changes color over time, in about 10 minutes, and becomes sort of different degrees of brown depending on how much arsenic is -- how much arsine is evolved from the solution from the [certified] water sample, that actually contains a smallest amount of mercury. It's mercury bromide is what's turning brown. So there's a disposal issue. It's certainly also not something you want children to put their hands on.

I think someone probably should look at this carefully and try to evaluate the relative risk of continued exposure to arsenic because you don't have a convenient way that you can just order to test your own well for arsenic versus the risk of touching the strip and not disposing of it properly. I think it's probably not a simple question, but someone should probably, with a toxicology background, should probably look at that.

So, I'll move on to the next slide and the next question, which is related in some ways, although it provides some specific, and so this question was should blanket testing of private wells for arsenic throughout the US be offered or imposed?

The imposed side -- I'm not going to really answer this question, in case you were concerned. I do note that in the US there are, sadly, many children who don't receive all the vaccinations they should, and there are deep reasons for that, and beliefs, so I think imposition is probably not going to go very far.

I should maybe point out a few things that I lined up here in the second slide. One is that the Safe Drinking Water Act of 1974 does not apply to domestic wells, so that all the public water supply systems need to comply, and I guess not all of them do yet. This act does not apply to domestic wells, and so that is a limitation on what can be expected.

The county health departments, as I pointed out earlier, they do carry out testing, but typically I've learned from Zoltan Szabo, who is at USGS in New Jersey, that this is typically limited to nitrate and bacteria. And so one obvious direction would be to encourage testing for arsenic, as well. And I think it's an open question on whether these should be laboratory tests, which take more time and are more costly, or whether they should be field-kit tests. My colleague, Yan Zheng, says that maybe the kits would have a bigger impact, a larger psychological impact and encourage households to take action once they find out their well is high in arsenic. It could still be important -- useful from that point of view.

Only one state in the US is my understanding requires water testing of a private well when the house changes hands, and this was passed in 2001. There have been attempts to pass this type of state-level legislature in North Carolina and New York and Maine, but it has failed so far. So this reminds me, of course, of radon testing. It looks like this is probably a direction that requires more efforts.

On the treatment side, I was told by Zoltan Szabo, again, that a number of states, including Maryland, also regulate the companies, the private companies, that offer treatment. And you want that, of course. You don't want someone to be selling a product that doesn't do what it claims to, and that is important.

I should point out just to wrap up that even if a well owner knows that a well is high in arsenic, just like in Bangladesh, it doesn't mean that this person is going to do something about it. People do engage in risky behaviors of various types.

And to put a number on that, what Yan Zheng and Sara Flanagan really found -- recently found in Maine is that on the order a little less than a third of the well owners would volunteer to have their well tested through the Community Engagement Core ended up not doing anything once they found out that their well was -- it had more than 10 mcg/liter arsenic in it. So you could say, well, two-thirds of them did, one-third of them did not. It would be unrealistic to expect that, even if these types of services, the testing were available for free and widely publicized, it doesn't necessarily mean that the entire population's exposure would necessarily be reduced.

If you are interested in further information, I've listed two links to recent papers that came out in a journal, in *Science of the Total Environment*, and Sara Flanagan is the author of both, and a lot of the information that I've tried to convey here just now is detailed in those two publications.

And I think I'll leave it at that.

Heather Henry: Thank you very much. At this time I'd like to open it up to our other panelists and see if they had anything to add or any follow-up, additional considerations based on the points that Dr. Van Geen is making in the questions that he's answering.

Also, anyone listening on the phones, again, you have the opportunity to ask questions, and I would encourage you to do so. Just look in the upper right panel and you'll find a question box where you can type in your questions to us.

So at this time I'd like to see if Mary, Megan, Julie or Raina had anything to add.

Mary Gamble: I don't, thanks -- Mary.

Julie Zimmerman: Hi, this is Julie. I'm going to talk about this a little bit in my section, but this questions of these kits and their accuracy and reliability is, I think, one of the areas that actually needs some more research in terms of developing kits that work in the field that are reliable that

have detection limits at the range we're talking about of 10 parts per billion, which is really hard to measure in the field.

Heather Henry: Thank you. Raina, did you have anything to add?

Alexander Van Geen: I could perhaps add -- respond to that.

Heather Henry: Oh, absolutely. Sure.

Alexander Van Geen: Yes? So I think that's a good point. When I think about arsenic in Bangladesh, though, often the exposure ranges over several orders of magnitude. It can be 1, it can be 10, it can be 100, it can be 1000 mcg/liter. So I've certainly felt when we started working in Bangladesh more than a decade ago that the analytical issues were sort of a secondary issue, that it was a red herring, to some extent. If you are in Bangladesh, the question whether someone was exposed to 40 or 60 mcg/liter was sort of a -- was a bit of a moot point. It made sense from the regulatory point of view for the country, because they are still using 50 mcg/liter. But in terms of my understanding from talking to Mary Gamble, to Joe Graziano, is that from a health point of view it is a rather arbitrary cut-off, and so that's why we've focused very much on field kits.

I should point out that the use of the field kits in Bangladesh, we've published a couple of papers in Science, Environmental Science and Technology, that document that they are perfectly adequate for a country like Bangladesh, with a very wide range of exposures. And I have less experience with them, but I can tell you that this company, ITS, they produce a kit where instead of reacting, adding acid and zinc powder to 50 mL samples you can add it up to 500 mL of water. And so that significantly decreases the detection limit, and I think you wouldn't have any trouble [distinguishing these] wells that have just a couple of ppb arsenic from somewhere between 10 and 15.

Heather Henry: And we got a question that came in from the audience, and this is directed to you, Dr. Van Geen. When testing for arsenic, does the results of the test provide suggestions as what to do to take action against high levels of arsenic?

Alexander Van Geen: Well, I'm told that the failures of either the RO systems or the iron-based adsorption media in Maine, the failures are more frequent if you have a high level of arsenic in your input water, not too surprisingly. And so it seems to me that one piece of information you should use is that if you know your level is, the higher that level the more frequently you should have that system checked. I don't think either of these two main approaches are particularly -- is better than the other in terms of treating the water and that you should choose one system versus the other just based on the arsenic level.

Heather Henry: Thank you. At this time I think we should move on to our next question. And we still will be glad to answer questions at the end, so we encourage listeners to submit as the question occurs to you.

But let's move on to our third panel discussion question, which is about the challenges and exposures for preventing arsenic exposures. So I'll pass it off to Julie now at this point.

Julie Zimmerman: Great. Thank you so much. I kept my slides pretty simple, looking at other folks' slides, but I'll make some points as I go through them.

So I think the first thing to think about is we need to provide safe (technical difficulty) water, and at (inaudible) there's a big push of whatever water we take out of a well needs to meet drinking water standards, and we need to think about where this water is being used and what the arsenic exposure routes might be. So drinking water is obviously one of the big ones.

There's some research that's shown that cooking food that is in water that is contaminated with arsenic will also lead to another exposure route, so thinking about food preparation and what water needs to be treated in order to serve that need. And then on a larger scale the other exposure route that requires attention is irrigation water for crops, where crops will then uptake arsenic, particularly rice is one of the ones that has been studied extensively.

So when the question is about biggest challenges and opportunities, I think one of the big challenges is the awareness and education and outreach, which the previous speaker just addressed, of this question of what knowledge do people have? And the other big challenge and also opportunity is to think about water infrastructure in a different way and matching what the intended use of that water is to the water quality that's needed. So this gets into a larger systemic question about providing safe, clean drinking water at the levels and quantities that we need and maybe not having to provide technology and arsenic removal units for water that's not going to be used either for drinking or food preparation or irrigation.

So I think it's a challenge because it's not how we typically think about water and the provision of water, especially in this country. All of the water, whether it's used for firefighting or showering, is treated to a drinking water quality standard level, and so how do we start to differentiate and match that water need with its potential use?

So I think those challenges also present opportunities, because if we lower the amount of water that needs to be treated to meet the arsenic healthy safe guidelines for drinking, which is very expensive and is often the pushback of that these small-scale systems can't meet the standard at a reasonable cost, but if we then were able to say you only need to treat this amount of water and deliver it for drinking or food preparation or irrigation to this concentration and you wouldn't be responsible to treat all of the water that's being delivered to the arsenic standard, I think it would change the conversation that's been going on.

The second point is this question of awareness, education and outreach. So there is a lot of confusion around these test kits and their reliability and functionality of maybe -- I think the speaker made a good point about this idea of in Bangladesh it's orders of magnitude difference, but in the US, if we're going to use these test kits, the standard is 10 parts per billion, there's questions about -- by EPA if that should even be lowered. How much of a variability are we willing to tolerate? And how reliable are these test kits?

So I've had a little bit of experience in West Bengal using them, and one of the challenges is getting consistent results from samples from similar wells dug to similar depths, and so that are very close proximity and get very different readings on these test kits. So I think there's a lot of opportunity there to pursue awareness and training about how to use these test kits and then what technologies might be appropriate, depending on the level that you're getting back in terms of what is the level of arsenic and what are you going to use that water for, which might dictate a different technology.

And then the next slide, please. So I just made this point a minute ago, but matching water quality to the intended use. And then my personal research has really been focused on developing technologies and collaborating with others who are trying to come up with technologies that will remove arsenic to the standard that has been set either by the US EPA in this country or by WHO globally.

One of the big challenges, just like with these test kits, is the appropriate disposal of removed arsenic. So one of the challenges once you remove that arsenic from the water, you've now either sorbed it onto a media or contained it in some other way, and so how are you going to dispose of that in a way that's not going to allow for recontamination of the aquifer?

There continues to be a lot of questions about what scale the appropriate technology should be designed to. So is this an individual responsibility? Is this a household scale, that each individual person would be responsible for their individual well? Or is it really a community-scale approach that we need to pursue in terms of cost and having the appropriate capacity to manage and operate these technologies? So what level of sophistication is appropriate?

This is also a really big question in terms of the community that's going to be served by the technology. So what level of treatment do you go in with? And maybe the most advanced technology that's going to get you to the lowest levels of arsenic contamination in the water is not really the appropriate technology to use for certain communities. So we need to do a lot more research on the social and cultural side of this question in terms of what is the capacity of these communities to adopt and use these technologies once they're designed.

So, we've found that a lot of the technologies work, and they work fine in the lab and they work even fine in the field, but when they're given to a community and then left, there's a lot of failure that happens at that point. And so at what level does the community get engaged? Is there is a cost of ownership that needs to be paid for these treatment technologies? Who is going to manage them? Who's going to monitor them? And who will enforce the standards? So there's a lot of social and cultural questions that go beyond the technologies that are being developed which also have questions, again, about household versus community scale and what is the right approach in terms of precipitation or coagulation or sorbing the arsenic out of the system.

My next point is thinking about from a technology perspective, it's been really challenging to find a technology that works and is appropriate in all the communities that need to be served. So as we worked in West Bengal and engaged different communities, every time we've approached a community it's basically been a new project. So I've had a hard time finding transferable and generalizable guidelines in terms of designing a technology that's going to be appropriate. And I

think if we need to approach this as a one community at a time problem it's too big, and it's going to be really hard to solve.

And so we need to figure out some guiding principles about technologies that will work and that are appropriate, and if we can start to parameterize the communities we're serving to understand who's there, what capacity do they have, what are their needs, how much drinking water versus other nonpotable uses need to be supplied, so that we can start matching technologies based on those community parameters rather than having to start over each time we need a new community. It's going to be a really big question going forward in terms of implementation.

And then my last point we discussed a little bit already, but I think this challenge of reliable, real-time, sensitive field detection is a really significant one. I've worked a little bit with the test kits, not incredibly extensively, but enough to have questions based on the data we're collecting in the field using the test kits versus the data we're getting from the same sample going to a laboratory and running ICPMS and being able to much more accurately measure those concentrations.

So how much reliance do you want to put on these test kits? How do you train people about what the results actually mean? How do you explain uncertainty in error bars? And, again, if we can get them to the point where this is an okay water source for nonpotable use versus potable use, that might be all we need in terms of you're better off going somewhere else for drinking water but this is fine for showering, and that gets back to the point of education and outreach and training that's required around this problem.

So I will stop there and take any questions.

Heather Henry: Thank you so much, Julie. This would be a great opportunity to hear from our other panelists, Mary, Megan, Lex or Raina, if you wanted to join in or have any follow-up questions for Julie.

Raina Maier: I have -- this is Raina -- I have a quick question. So I know that there are antibody-based test kits and there are even some available for metal. I have no idea if one is available for arsenic. Does anybody on the panel know?

Julie Zimmerman: Test -- I'm sorry, for water concentration, or --

Raina Maier: Yes, for water concentration.

Julie Zimmerman: Yes, there are a couple out there on the market. I think the -- I didn't catch your name, I'm sorry, the previous speaker mentioned there's even some for sale on Amazon. They rely on not super-great chemical reaction, so they often use mercury, so you're creating another toxic contaminant that you then have to manage on the disposal stream, and they're also color-metric in the field, so if you're looking at, if you're like familiar with a swimming pool and pH test kit, right, where you measure and you get pink to blue, these arsenic test kits go from beige to brown, and depending on the darkness of the color you get is an indication of how much arsenic is present in the water.

Raina Maier: Right. So, yes, I understood that they used the toxic chemicals, but there are antibody-based test kits that are used and approved by both FDA and EPA for things like 24D and even some metals. Do you know whether there's a test kit available for arsenic?

Julie Zimmerman: I have not seen one, but --

Alexander Van Geen: There is one group at [AOAC] that's developed an E. coli based kit, then so it somehow it bioluminesces. And so that's a group by -- yes, at AOAC. It came out in the ES&T in 2005. And then I know there's another bio-arsenic detector that's being developed by a group at Imperial College. So these things are taking place. There's also a German group that I think was sort of building on the E. coli experience.

They're not exactly easy to use. I think -- I'm quite open minded. I'd like to have a better kit. But, so, and the toxicity of the chemicals, I mean, the zinc is not particularly toxic, and neither is the tartaric acid. It's the mercury is really the main issue in the arsine that's being produced.

I'd like to follow up on what I heard just a little while ago, and I'm glad that you have some experience, Julie, in West Bengal. And you're absolutely right that there's a tremendous spatial variability, so wells from the same village that are exactly the same depth, they can have very different arsenic levels. But that reflects really the natural variability of the system. That is a separate question from the reproducibility of the measurement itself, the analytical capabilities of the kit. And so I just wanted to make sure that people were not confused by that. Spatial variability I agree with you completely. Reproducibility for a particular water, I think those kits do pretty well, and that's what we've been writing about in a number of papers.

Heather Henry: Thanks. Julie, did you want to respond back, or Mary and Megan, any other thing to add?

Julie Zimmerman: Yes, so thank you for clarifying. Yes, so there is a lot of spatial variability in using those test kits. But we also, when we were taking water samples from various wells in West Bengal that were near each other and running test kits versus ICPMS, we were seeing different results. But those water samples, getting to a place where we could run ICPMS, were not -- storage is a big question, and temperature changes and how they were managed. So I don't want to say -- we didn't publish those results, but it was enough for me to question how much credence we want to say that, yes, this measured at 10 parts per billion and it's safe for drinking versus at 20 or 30 and maybe it's not a good drinking water source. I don't have a good handle on the error bars or standard deviation of the results that come out of those test kits right now.

Megan Hall: Julie, just to clarify -- this is Megan -- so you're talking about water sample from the same well measured using a test kit and then measured using ICPMS?

Julie Zimmerman: Correct.

Megan Hall: Okay.

Julie Zimmerman: But it took us two weeks to get to an ICPMS --

Megan Hall: Mm-hmm.

Julie Zimmerman: -- from those same samples, so, again, I don't have a good -- it wasn't like we took it, we froze it and we shipped it, right? So we had to carry it with us, and it was exposed to temperature and all kinds of other issues. And so I didn't -- we can't and didn't publish those results, but it was enough for me to begin to question how much guidance we want to say this tested safe and it's good for drinking water versus using it in another way of saying this is probably not good for drinking water and use it for other intended purposes, nonpotable use.

Megan Hall: Mm-hmm. I see. Thank you.

Heather Henry: Great. Thanks. We're at the 15-minute point, so I think this is a good time to thank Julie and move on to our next question, although, again, we encourage those questions to keep coming in, and we do anticipate having time at the end to really start to put all these different thoughts together and consider some of the additional questions that are coming in. Thank you very much, Julie.

At this time let's move on to Dr. Raina Maier. She's going to be talking about natural sources of arsenic and considering, again, how exposure and prevention line up with some of these anthropogenic sources. So, Raina?

Raina Maier: Thank you, Heather. The first question that I'll talk about is arsenic is an interesting toxicant, because much of the exposure occurs from natural sources. What exposures occur due to anthropogenic processing?

And so you all have just heard a great summary of naturally occurring sources of arsenic, especially in drinking water. But actually arsenic is associated with more than 200 different minerals that are found in the earth's crust. And one of the major minerals associated with arsenic is arsenopyrite, and I'm going to come back to that mineral later on.

So, the reason arsenic gets into drinking water is that it naturally leaches out of these minerals into groundwater and it creates some of the drinking water issues that we've been hearing about. But there are a variety of human activities that disturb the earth's crust and result in enhanced release of arsenic into the environment.

And so in this slide I've got two bullets. And the first bullet talks about how anthropogenic activities that disturb the earth's crust can release arsenic into the environment, beginning with mining and mining-related activities.

So, often the ores that we mine for metals of economic value like copper are also rich in arsenopyrite, which I just mentioned. And when you dig those ores out of the ground, this arsenopyrite, which is an arsenic sulfide, basically, a reduced ore, when you dig them out of the ground they're exposed to oxygen, and that allows oxidation of the arsenopyrite and release of arsenic into the soil and into the water.

And so, in addition to mining and mining-related activities, we also have coal burning. So for the same reason, when you dig up coal as a resource it's often contaminated with arsenopyrite, and so when you burn the coal you release arsenic into the atmosphere.

The increased interest in the use of geothermal power, and arsenic is commonly elevated in geothermal fluids, and so this can lead to contamination of waterways into which the geothermal fluids are released after they're used to generate energy. So all of these are examples of how when humans dig into the earth's crust we start releasing arsenic.

And I'm going to just mention that I'm from the West Coast. Everybody else who has talked before me is from the East Coast. And in the West our climate is quite different, so we have an arid, dry climate. And so in addition to arsenic in water, we have arsenic in our soils. And because it's so dry we get a lot of dust blowing around. And so we also have to start thinking about different types of exposure routes. So in the West not only do we get exposed to arsenic in our drinking water, but we can also be exposed to elevated levels of arsenic from inhalation of dust or even ingestion of soils.

So the second type of human activity that I'd like to talk about is that we have used this amazing chemical, arsenic, to control pests, and it's very effective at doing that. So we have used chromated copper arsenate, or CCA, to treat wood, and that was very, very commonly used in residential building, and in fact in building playgrounds for children. And due to elevated concern over exposure of children to arsenic from this wood, the use of CCA was terminated, in the US, at least, in about 2003.

We have also since the 1930s or 1940s used arsenic feed additive for poultry and swine production. That feed additive is known as roxarsone. And a voluntary suspension of roxarsone occurred in 2011 because they were finding elevated levels of arsenic in chicken tissue.

And then, finally, we have used organic arsenicals as insecticides, as we've used them on a large, large number of crops. And their use, again because of arsenic exposure concerns, was largely phased out in the US from 2009 -- between 2009 and 2013, except for the use on cotton. And probably the best example that people listening to this webinar have heard is arsenic in apple juice. And so organic arsenicals were used in apple orchards quite commonly, and there are elevated levels of arsenic in some samples of apple juice on the market. And, of course, once you contaminate soil with arsenic, that remains for a long period of time.

Next slide, please. So my second part of my question is how can we evaluate these exposures. So we've gotten really good at evaluating the amount of arsenic in different sources. So we know how to evaluate the amounts of arsenic and even speciation of arsenic in water, in soils and dust and food. We also know quite well, as you've heard today, how to measure arsenic exposure in human populations.

What we haven't done quite so well is to partner those studies together. And so I would say a big data gap right now is looking at communities that live in an arsenic area and an arsenic area that might have not only arsenic in drinking water but arsenic in soils, and perhaps people do home

gardening, so you may have uptake of arsenic into vegetables that these people grow. And so we need some partnered studies looking at what is the entire intake of arsenic into a human living in an area in which there might be a variety of different types of exposures to arsenic.

Last slide, please. So the third part of my question is what types of prevention strategies are there to minimize arsenic exposures from anthropogenic sources. So, this is a little bit difficult. I think it was either Mary or Megan that said reduction through remediation should always be the first priority, and I really, truly agree with that. But some of the anthropogenic release of arsenic into the environment is so extensive that it's going to be hard to remediate these huge tracts of land or even waterways.

And so I think part of what we need to do is community prevention, and that is providing communities with information on home behaviors. And this is particularly for the US West and other arid and semi-arid environments. So teach people to remove outdoor shoes and clothing and use appropriate handwashing, and that can minimize tracking of soil and dust into homes.

Also, in terms of community prevention, we need to provide better information on foods that have high levels of arsenic to communities to allow them to make better informed dietary decisions. So, for example, it's not that they should stop eating these foods, but maybe they should have a bigger variety of foods in their diet and maybe use a little less of these types of foods that might be high in arsenic, like rice and rice products, apple juice and dark meat fish, just as some examples.

And I would like to end by giving you an example from some of the work that we're doing at our Arizona Superfund Program with a community that neighbors a mining-impacted Superfund site. So we went into this community and asked them what is of concern to them living next to a Superfund site, and what they told us they were concerned was it safe for them to consume the vegetables that they were growing in their gardens.

And so we worked with them to do a home gardening study. They provided us with vegetables grown in their gardens, and we analyzed those vegetables to look at uptake of arsenic into plant tissues, and this can be either endemic or anthropogenic arsenic. And we were able to show that some groups or families of vegetables take up much more arsenic than others. And so, again, this is information then we can provide to the community so they can make decisions on what to grow in their garden and how much to eat of what they grow in their garden. So, really, I think a lot of this is an effort to educate the community and let them make informed decisions about what they want to consume.

So that's -- I'd be happy to answer any questions.

Heather Henry: Thank you, Raina. At this time I can open it up to our other panelists and see if there are any follow-on questions that they have for Raina based on the points that she raised for the anthropogenic forms of arsenic.

Mary Gamble: Sure, I'd like to respond to Raina's comment on one of the things that we said and perhaps slightly misspoke. So I think, Megan, it's one of Megan's slides that a first effort should

be always at remediation, and it probably should have been at remediation and prevention strategies, including those that you mentioned. The context for that is really that some people, believe or not, actually say, oh, so we don't have to lower exposure, we can just give people folate, and that's sort of what we're getting.

Raina Maier: But I agree with that. Remediation really should be the way to go, but sometimes it's just so extensive.

Mary Gamble: Yes, no, I really understand.

Raina Maier: Yes.

Alexander Van Geen: I have suggestions for Raina if I can make it.

Raina Maier: I'd love to hear your suggestions.

Alexander Van Geen: So, as Mary and Megan will know, I'm a big fan of kits, and I can tell you that we just got funded by NSF for a pretty large study where we're going to map the amount of arsenic in rice paddy soil in Bangladesh, using the same kits, so just taking a gram of soil, adding it to 50 mL of water, letting it react the usual way. And we've already demonstrated that it's really quite linear in terms of its response for soil arsenic levels between five and 50 ppm arsenic. And maybe some of the areas that you are studying where soil can be contaminated, maybe that's amenable to people using the kit for that purpose.

Raina Maier: Yes, I think we should probably try it. I think that's a good idea. Because, as you know, taking it back to the lab and doing extractions in ICPMS, it gets expensive.

Alexander Van Geen: Right, right, and also, yes, you could have many more sort of individual families check the yard where their children are playing. I mean, I'm saying this more from a (inaudible) of lead, where we're working on a different kit, but I can tell you that for arsenic, especially because the arsine essentially separates the arsenic from the matrix, I think it actually is an easier problem maybe to solve than getting lead of soil and then measuring that, say, (inaudible).

Raina Maier: Mm-hmm. And I think those are really important studies to do. We've also seen with the materials that we've been working with that determining bioaccessibility and down the line even bioavailability of these contaminants, it's really important and will be important for risk assessment, because not all media -- the arsenic in each media -- medium can behave very differently in terms of its bioaccessibility and bioavailability.

Alexander Van Geen: That's right. And so in some ways a sort of operational definition based on some reaction could be more appropriate than a bulk arsenic measurement by x-ray fluorescence.

Raina Maier: Yes, I agree with that. Yes.

Heather Henry: Any other comments from our panelists?

Megan Hall: Hi, this is Megan. Raina, I just wanted to respond to your point about taking into account arsenic exposure from multiple sources, including water, food, anthropogenic sources. I completely agree with that, and I'm thinking in terms of our studies that we work on in Bangladesh we've been primarily concerned with arsenic exposure from water, given how high the -- on average how high the arsenic exposure is through water in our study area. But I think there's probably a lot more that we could do to try to assess arsenic exposure from food in more detail, and particularly when water arsenic exposure is low, arsenic exposure through food will make a bigger contribution to total exposure, and that will help us to get a better handle on total arsenic exposures and better characterizing that exposure.

Raina Maier: So you're exactly right. I think in Bangladesh the exposure is overwhelmed by the water. But I think in many other parts of the world, and particularly in arid environments, ingestion of soil by children, pica, and dust, I think, becomes extremely important. And we have actually shown in our community next to our Superfund site that urinary and toenail arsenic is related to the arsenic in the dust in the home, is correlated to -- significantly correlated to. And so we think that in some of these areas that in addition to water exposure these other exposures may be very important.

Megan Hall: Absolutely. I agree.

Heather Henry: Great. Thanks. One last chance for our panelists. Okay, well, we have a number of questions that came in online, and I will pass this over to Michelle Heacock, from NIEHS, to address those questions that came in.

Michelle Heacock: Okay, thanks, Heather. We have a couple questions for Raina, and then we have a couple questions from the other sessions' questions.

So the first one is does clean coal technology reduce arsenic output into the local environment?

Raina Maier: Oh, my goodness. I can't answer that question. My apologies. I'm not sure what clean coal technology does in terms of arsenic. Sorry.

Michelle Heacock: That's okay. So the second question is -- and if anyone knows the answer to that, please feel free to send it through the question portal, or if any of the panelists know, please feel free to chime in -- so in the meantime, the second question is with increasing burning of coal in countries like China, is it anticipated that their populations are more susceptible to arsenic toxicity in the future?

Raina Maier: Well, I think that the increase in coal burning in China has a lot of different impacts, and arsenic is only one of them. So it has huge impacts on other types of air quality, but arsenic is right in there. And as we mine more and more coal, in general the types of coal that we get to are lower quality and lower grade as we use up the better grade ores. So I would expect that issues in terms of the quality of coal we're burning will get bigger.

Michelle Heacock: Okay, thank you, Raina.

Heather Henry: Do other panelists want to weigh in on either of the two questions that just came up, either about the clean coal technology reducing arsenic or whether we might anticipate more issues due to the increased coal burning, particularly in China?

Michelle Heacock: Okay, so we'll -- this question is for -- I think it's -- I believe it's directed towards Mary and Megan, and the question is many of the nutritional interventions described relate to arsenic metabolism. Given that epidemiologic evidence shows increased risk of cancers even after exposure has terminated, what are the speaker's thoughts on implementing nutritional interventions for historically exposed populations? I kind of muddled that. I hope that came through.

Mary Gamble: No, that came through. So if I understand the question correctly, the person is asking are we considering nutritional interventions in populations with historical exposure who are no longer exposed. Is that correct?

Michelle Heacock: Exactly. Given with the -- taking into consideration that there's an increased cancer risk.

Mary Gamble: Right. We don't have plans to do that at the moment. As Megan mentioned, the health -- showing primary prevention, for example, of a cancer outcomes requires enormous study populations. One way you can kind of get around it is you can -- there may be populations in which, such as, perhaps in Chile, where there's historical arsenic exposure and at some point food fortification programs went into place. So I think there probably are some creative study designs that you could do that beyond the clinical trials. Clinical trials for that particular type of outcome, a cancer outcome in populations no longer exposed, would require many, many thousands of people and would be just enormously expensive, unfortunately.

Megan, did you want to add anything to that?

Megan Hall: No, other than we would love to do those types of studies, but they're probably just not feasible for cost and time reasons.

Michelle Heacock: Okay, and did anyone else have anything to add?

Mary Gamble: I could also say that it might be feasible to look at other health-related outcomes. They're actually seeing in Bangladesh a stronger link to cardiovascular disease and that's a higher prevalence. So that kind of a topic is more approachable, because it's not such a rare outcome.

Michelle Heacock: This next question, I believe this is directed to Lex. And so this is about the testing kits. Oh, so another question just came in and took it away. Just a second. The cost of water testing, either lab or kit, would be a higher burden for the low-income populations. Is there any funding source available to help out vulnerable populations to find out whether their water levels -- what their arsenic water levels are and to take the appropriate measures, so, for example, using bottled water or installing a filtration system?

Alexander Van Geen: I'm not aware of funding sources. It seems to me that maybe this is where politics are supposed to play a role, right? Disadvantaged populations will vote, as well. And so what you'd like is somehow to organize this community so that whoever decides these kinds of allocations is aware that the population cares about it and wants to funnel a portion of tax revenue in that direction. I'm afraid that's all I can say about that.

Michelle Heacock: Okay, thanks, Lex. So the next question is if the water used for irrigation on crop land is contaminated with arsenic, how do you avoid using that for crop irrigation? Is there a filtration system for crop irrigation likely or realistic?

Alexander Van Geen: Well, it's already quite difficult to treat the water for arsenic when it is meant to be consumed or cooked with, and irrigation, in Bangladesh, for instance, use about 100 times more water per surface area than is required for drinking and cooking. So it's a very tough challenge. Some of our colleagues, including Matt Polizzotto, is working on systems to try to use the fact that the iron comes up with iron to drop out with the arsenic. But I'm not very optimistic on how successful this will be.

One aspect that could be done much more is instead of relying on groundwater is to go back, to some extent, to using surface water. There's plenty of water in South Asia. The issue is how to get it to a particular field. And there used to be a lot more (inaudible), I'm told. A good book by someone named (inaudible) has been written by that. The fact that so many farmers in South Asia use their own irrigation well and (installed) it is because they couldn't rely on the surface water supply that used to be there. A lot of these systems were installed in the colonial days under the British and were maintained by them, but as that became less reliable farmers had essentially no choice but to come up with their own solution, and in this case it turns out that it's arsenic -- groundwater is used that is high in arsenic for irrigation.

I should point out that very quickly is that arsenic in rice is an issue, but in Bangladesh, as Raina pointed out, the main issue remains arsenic in drinking water. And what is significant is the fact that the yields of rice go down as the arsenic builds up in rice paddies. John Duxbury's group at Cornell has shown that rather convincingly, and that is a serious source of concern at present.

Heather Henry: If I could even -- this is Heather -- if I could ask Raina to weigh in on that last question, if there are one or two things you wanted to mention. In particular, you had given a talk during the actual arsenic meeting, the arsenic workshop, you'd given a talk about some of the research you've done. So I didn't know if you wanted to comment about soil amendments, what we know about that, because I imagine that can be used in an agricultural setting should that be necessary.

Raina Maier: Yes, so I -- can you hear me?

Heather Henry: Yes.

Raina Maier: Okay. Our research is looking at trying to establish vegetative caps on mining waste, in particular mine tailings. And the mine tailings that we work with have highly elevated

arsenic levels, up to a half a percent. And what we're finding is that in the (inaudible) of the plants over time as the plants establish the arsenic is being incorporated into neoformed mineral phases, which are much less bioaccessible than the arsenic in the original tailings. And so we're seeing some of these plants' processes help stabilize the arsenic in situ. That's been very, very interesting for us in the sites that we've been working at.

I'm not sure how that translates into growing crops like rice, and I actually think that would be a very interesting research question to look at is to look at speciation of arsenic over time as you're growing rice in these paddies.

And if I can go back a minute to the clean coal question, I actually Googled it while we've been talking, and apparently clean coal technology removes about 80 percent of the arsenic that's in the coal. And that's important, because arsenic acts as a poison for the clean technology process.

Michelle Heacock: There's one more question. It says I think the difficulty in giving advice about what to eat is that we do not have good risk data. How do you go about giving advice?

Raina Maier: I think that that's absolutely right, and I think that is a big knowledge gap right now. We don't have good enough data to put into risk assessment models. We need further exposure studies. And that's what I was trying to get at in my second slide is that we need partnered studies that sort of look holistically at how the arsenic exists in the environment and then how -- when humans ingest it how they process it. And I think until we can do that a little better, we won't be able to with 100 percent accuracy give good risk assessments.

Heather Henry: Thank you. And does that conclude our online questions? Okay. And I did just have one follow-up question, Raina, particularly for you, talking about anthropogenic sources. And just to put it out there, and I don't know the answer, but I've heard that with hydraulic fracturing a lot of times the flowback water will have high levels of minerals, arsenic being one of the minerals that's in high concentration. I didn't know if that is a potential additional source that might -- we might be on the lookout for.

Raina Maier: I think you're absolutely right and that it is. I think any time you're disturbing the earth's crust and there are elevated levels of arsenic in the crust you're going to be releasing some of that arsenic into the water system in the (inaudible) zone or the saturated zone.

Heather Henry: Okay, great. Thanks. Oh, at this time I'd like to thank all of our panelists for these informative discussions and to NIEHS for organizing this webinar series, under the leadership of Danielle Carlin. I will now turn it over to Danielle to close the session.

Danielle Carlin: Well, thanks, Heather, so much, for moderating such a terrific session today.

I would like to conclude this webinar, but before doing so I want to provide just a few closing remarks, just to reiterate that this is the last webinar in our panel discussion series, and we just would like to thank everybody for their patience with all of the -- some of the technical difficulties. But I think we've done an awesome job.

So I also want everybody to know that we received approval to have these webinars posted on our website, and they should be available in the next few weeks. So those will include the PowerPoint presentations, an audio file of the webinars as well as a transcript, a written transcript for you all to read. So I encourage you to check the NIEHS Arsenic Workshop website often. And if you can switch to the next slide, please. So, as you can see on the bottom, that's where you would see the website that will contain all of the webinars there.

And if I can go to the next slide, please. Okay, so this, again, I'm going to be concluding, and I just want to acknowledge again our moderator, Dr. Heather Henry, today. I'd like to thank all of our panelists, Dr. Gamble, Dr. Hall, Dr. Van Geen, Dr. Zimmerman and Dr. Maier for doing an excellent job at presenting their thoughts about each question.

I'd also like to thank all of my colleagues within the Superfund Research Program and thank Dr. Michelle Heacock for fielding all of the questions today and thank Justin Crane and Maureen Avakian from MDB, Inc. They helped keep everything running smoothly over here. And then, finally, Dr. Marisa Naujokas for her assistance on the Workshop Publication.

So with that, again, I'd like to just thank everybody that's been involved in making these panel webinars -- panel discussion webinars a success, and especially to the audience, as well, for such wonderful questions. And if you have any questions you are also welcome to email me directly, danielle.carlin@NIH.gov, or you can also visit our website, which is listed there in the bottom, for all the information regarding the workshop as well as these panel discussions.

So with that, have a great afternoon, and we look forward to seeing you at a future workshop.