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“The Arsenic Rule”

Tami: Welcome, ladies and gentlemen, to today’s seminar on “The Arsenic Rule,” powered by Encounter Web conferencing. Before we begin today’s seminar, I would like to review a few housekeeping items. First of all, if you haven’t clicked on the meeting URL link provided to you in your invitation email, please do so now. This will launch today’s web seminar. If you have any problems with the audio or web portion of today’s event, please contact Customer Care by pressing \*0 on your telephone keypad.

You may submit text questions anytime during today’s seminar. Simply click on the “Ask Question” button located in the lower right hand corner of your screen, type your question and click “Ask.” We will try and answer as many questions as possible while still keeping to the agenda. You can also press Control H on your keyboard to toggle your screen between regular view and expanded view. Again, should you need help at any time during this seminar, press \*0 for an operator.

At this time, I’d like to introduce our moderator for today, Andrea Matzke from EPA’s Protection Branch in the Office of Groundwater and Drinking Water. Andrea, you have the floor.

Andrea: Thanks, Tami. I’d like to welcome everyone to the first of two Web cast trainings on the Arsenic Rule. Today’s training will focus on treatment technologies. As Tami mentioned, I’m Andrea Matzke and I work on Arsenic and Radionuclide Rules implementation in the Office of Groundwater and Drinking Water’s Drinking Water Protection Division here in Washington, D.C. Today we have six presentations on treatment technology issues, including a panel discussion on two small systems that were included in Round 1 of the Arsenic Demonstration Projects. We did have requests in the past to include photos of presenters, so here we all are at popular request.

I would like to leave a minute at the end of each presentation to answer any questions that come in from the audience. We’ll also have 10 minutes at the end of the Web cast to address questions targeted toward all the presenters. As before in earlier Web casts, we will provide written documentation of all the questions that were answered, as well as some of the questions that could not be addressed during the Web cast. We do appreciate your patience in allowing some time before this question and answer list is posted onto our Drinking Water Academy Web site. It does take some time. And actually, those who viewed the radionuclide Web cast several months ago, that question and answer document is up on our Web site now. We’ll also be recording this session and post both the written and audio files on the same Web site.

So with that, I’d like to introduce our first speaker. He’s Tom Sorg and Tom is a research engineer for the Water Supply and Water Resources Division in the Office of Research and Development at EPA in Cincinnati. He has a B.S. and M.S. in civil environmental engineering from the University of Notre Dame and he’s a registered P.E.

in the State of Ohio. Tom has over 40 years of experience with environmental programs for the federal government and has spent the last 31 years with the Drinking Water Research and Development Program of EPA. For 25 years, Tom has been chief of the Inorganics and Particulate Control Branch of the Drinking Water Research Division. His special emphasis of research work has been on drinking water treatment technology for the removal of inorganic and radionuclide contaminants from water supplies, including the removal of arsenic. During the past 5 years, his research has focused on treatment technologies to remove arsenic from drinking water in support of the revised arsenic MCL of 10 µg/L. This effort has included the responsibility for the arsenic removal full-scale demonstration program. Tom has authored over sixty publications on drinking water treatment and is a member of AWWAMAAEE. So, with that, Tom, are you set to go?

Tom: Let's go. Good afternoon everyone. The section on treatment options is going to be broken down into two parts. I'm going to take about 20 minutes to cover the first part and then Darren Lytle, one of my coworkers here, will be covering the second part. In my first part, I'm going to talk briefly about arsenic chemistry and then a few words about best available technology and then finish up with adsorptive media technology. Regarding the arsenic chemistry, if you recall from your Chemistry 101, arsenic is a cation with a charge of +3 and +5, but in water it reacts with water and forms various species. The ones I've highlighted here in bold for Arsenic (III) occurs in the general pH range of 6.5 to 8.5, which is the common pH range for groundwater. For Arsenic (V), there are two species, both shown here on the slide. The key difference with Arsenic (III) is that the species for Arsenic (III) has no charge. For Arsenic (V), of the two species, one has a -1 and the second one a -2.

Now you might ask: "what's the significance of the arsenic speciation?" Well, the important part is that Arsenic (V) is more effectively removed than Arsenic (III) by most of the treatment technologies that we're using for arsenic removal. Therefore, to achieve maximum removal, you want to oxidize Arsenic (III) to Arsenic (V) before applying treatment.

Now you might ask: "how do you oxidize Arsenic (III) to Arsenic (V)?" Well, there are a number of ways. First there are three chemical oxidants that are very effective; free chlorine, potassium permanganate, and ozone. There are some solid oxidizing medias on the market that go under the trade names of Pyrolox and Filox - these are solid materials. They're basically a manganese dioxide and they can also oxidize Arsenic (III). Chloramines, chlorine dioxide, and UV radiation are not effective. The question always comes up about aeration. Will aeration oxidize Arsenic (III) as it does Iron (II) to Iron (III)? And the answer is no. It's very, very, slow and it's not effective.

To move onto BAT technology, when the Arsenic Rule came out, the Agency listed seven different technologies under best available technology. To make the list, you have to achieve seven different criteria. I've listed only one here in the right hand column and that has to deal with percent removal and the criteria is it has to have a high

percent removal, generally 80% or more. And these seven technologies can achieve 80% or more removal with Arsenic (V). So the BAT is based upon arsenic being in the Arsenic (V) form. The arsenic technologies listed are ion exchange, activated alumina, reverse osmosis, and so on down the line to the very last one where it says oxidation/filtration with an iron to arsenic ratio of 20 to 1. This last one really refers to iron removal processes and this would be used when you have rather high iron in your water and it's effective when the ratio of iron to arsenic is 20 to 1.

The Rule also discusses several other groundwater processes; two of them that were mentioned in the Rule are coagulation-assisted microfiltration and GFH. Coagulation-assisted microfiltration is effective, but there was no full-scale history to allow it to be listed as BAT. Another one that was discussed was GFH, which is a granular ferric hydroxide adsorption media. This did not make the list because at that time there was a lack of published data. But we know both of these technologies are fairly effective. For small systems, compliance for centralized treatment - it's the same as the initial list, but it also includes point-of-use reverse osmosis, activated alumina and for point-of-entry activated alumina.

Now, a very frequently asked question, at least to me, is: "what would be the first thing you would want to consider when beginning to decide on an arsenic removal technology?" And my response, which is my opinion, is that the first thing you want to examine is the level of arsenic in your source water. Iron is an excellent adsorptive media for arsenic and whether it be an iron media, an iron floc from an iron coagulant, or the natural precipitated iron. Therefore, if the natural iron content of your source water is high - particularly if it's above 0.03 mg/L - then you should take advantage of it and consider it as probably one of your first options for arsenic removal.

I put together this little process guide, which to me is a very simple guide, and it relates arsenic to iron. And if you look on the left hand side, it shows arsenic and then on the bottom of the curve is iron. The graph is broken up into a couple of different areas. The key part is the iron MCL, 0.03 mg/L. If you're above 0.03 mg/L in iron, you probably want to consider arsenic removal by removing the iron. If you remove the iron you will remove the arsenic.

I've broken this up into two parts: an A and a B. If you fall into the A region, that means that you probably have enough iron in your natural water that once you precipitate it, you will remove the arsenic. If you're in Section B, that means you have some iron but probably not enough to reduce the arsenic to below 10 µg/L. Darren will be discussing the iron removal technology related to Sections A and B. Now if you have very low iron, which would put you in the C area, you then have to begin to look at other technologies such as media adsorption - maybe ion exchange or even one of the membrane processes.

I'm going to move on in the last few minutes that I have to talk about adsorptive media. The reason we selected to talk about that today is that it is one of the processes that many of the small communities are selecting to remove their arsenic. For example,

in our Arsenic Demonstration Program in Round 1, we have twelve sites and nine of those twelve sites have opted to use the adsorptive media process. So it is one that is being frequently considered and being used by many small systems. I put on a 2-day workshop about 3 or 4 weeks ago here in Cincinnati on the design and operation of the adsorptive media process for arsenic removal and in my few minutes here, I'm going to try to cover the 2-day workshop in about 10 minutes. So you're going to get just some of the highlights.

First of all, what are some of the advantages of the adsorptive media process? First, it's very simple. It's a fixed bed process. The capacity for most medias is rather high. Waste products are generally not hazardous and can be disposed of in a normal landfill and relative to other technologies, it's low cost. There are certainly some disadvantages. The removal capacity with most materials is impacted by water chemistry such as pH. The lower the pH, generally the higher the removal capacity and it may well be that you may have to adjust pH to make the process economical and, of course, you have to replace the media, which is an expense and takes a little bit of time.

As far as the adsorptive media design factors, there are a number of them that you need to consider when you're designing the process. I pulled out two, which I consider probably the key ones. One is the selection of the media and the second one is the bed configuration. This next slide shows a list of the adsorptive medias that have been published by NSF under Standard 61. Now I pulled this out a couple of years ago and I know there are more medias that have been listed under Standard 61 since I put together this list. One of them is titanium dioxide media by Hydroglobe and I just mention that to show that there are different base materials, but if you look at this list, most of them are either aluminum-based or iron-based. There are some products - zirconium as I said, titanium dioxide. So there is a wide variety of products on the market and they have different names because they're produced by different companies.

The medias have different capabilities and different capacities. This slide here (Figure 1) just shows the results of a pilot study that we completed here at a site in Ohio. I brought this in just to show you that there are differences between performance among the different medias. As you will see in this slide, two of the medias have outperformed the rest of them. One is the GFH and the other one is the E33. This information was developed from pilot plant studies. There's a lot of research going on using laboratory studies and of course, the manufacturers with time will have more and more information on how these products perform under varying water characteristics. The question always comes up about whether you need to conduct pilot studies in all cases. I think the manufacturers are gathering more and more data where they're able to make fairly good predictions based upon water qualities.

This slide here shows the system that we used to do our pilot work at the site in Ohio. So it may well be in some circumstances you may feel it necessary to do some pilot work. Now as far as bed configuration, there are two fundamental designs. One is putting the beds in parallel and the second way is to use them in series. The simplest, of course, is beds in series, either one bed, maybe a two bed or a three bed and these can be

expanded to add additional vessels if you decide to expand your water supply. In this case, the media comes into the bed and it's removed. The media must be replaced, however, when you are either close to or at the MCL of 10 µg/L. It's the simplest of the two bed designs. The other possibility - and this is a more conservative design - are two beds in series. In this case, you will have the first bed, which is used as a roughing filter and then this is followed by a second bed, which we call the polishing filter. As I said, this is a more conservative design.

This next slide just shows you a sample of a system in New Hampshire. It's similar to the slide before that where you have four tanks, with two tanks in series and two sets of them. Now this is the results of monitoring that set of vessels. The thing I want to point out here in this slide is that you're capable of using the total capacity of the roughing filter. In this slide here, the raw water arsenic concentration was around 60 µg/L. We monitored the arsenic coming out of the roughing tanks and also out of the polishing tanks. In this case, because you have a set in series, you can allow the arsenic to continue to be removed past breakthrough in the roughing filters - so you can use the full capacity. So in this case (at the bottom of the slide) it's reported in weeks.

At the end of about 40 weeks the arsenic in the effluent from the roughing filter was approaching the influent and at that time they then changed out the filter. When you do this, you need to then replace the two roughing filter columns (or the media in the two roughing filter vessels) with virgin media and when you do that, you then reverse their positions. You move the polishing filter into the first position and then put the new material into the second position and this gives you a little factor of safety because of breakthrough from the roughing filter.

Now I'm close to my time and I know questions have come up about the cost of the adsorption media systems. This is data that we put together from our Demonstration Program Round 1. All nine of these systems are currently in place and this gives you some of the cost information. As you can see, we have three of the systems in series design and the rest of them in parallel. I've included the total capital investment costs and that includes the equipment, the installation, and all the engineering, and then for your interest, I've included the equipment costs. For the most part, as you increase the size of the system, as you would expect, the cost will go up. You have to look very carefully at how these numbers were put together because each system is slightly different and some systems have more monitoring equipment associated with them. Some systems have pH adjustments, some do not. Some have holding tanks for recycle of the backwash water and this can account for some of the higher cost in some of the systems that you would expect to be much lower. I've included the percent of equipment cost as part of the total investment cost. So this information just gives you some rough cost information. With this, I'm going to conclude my remarks and we may have time for maybe one question or two.

Andrea: Thanks, Tom. I don't think we had any questions that came in. So we could go on, but actually I just wanted to take this opportunity to remind people that we did upload various documents on implementation for the Arsenic Rule as well as various

design manuals that Tom's office has produced. So when you registered, I think you saw a whole bunch of documents. I think there's some really good ones there if you hadn't had a chance to check them out. There's also one, the design manual for small systems, and there's a companion piece with the decision trees that basically is an interactive program for the design manual that, again, if you haven't had a chance to check that out, it might be worth doing so.

Tami: And Andrea, this is Tami, I did want to let people know as well, to find those they can retrieve them on the page that they entered in on. So if they just go back to that page that they clicked on the Join Now button, they're all there and they're ready to download.

Andrea: Great, thanks, Tami, and again if you're not able to download at that point, you can always go to our Web site or to the ORD's Web site, the Office of Research and Development's Web site as well.

Tom: Andrea, if I can add, we do have hardbound copies of all the reports for people who may want a hardbound copy.

Andrea: Okay, great. Looks like we did get a question that came in. Are potential costs included in downloadable documents? I don't know Tom, are there any costs associated with those documents?

Tom: No.

Andrea: Ok. That answers your question. Well thanks Tom, I think we'll go on to our next speaker, Darren Lytle who will continue the treatment technology talk. Darren received his B.S. in civil engineering from the University of Akron in 1990. In 1991, he received an M.S. in environmental engineering from the University of Cincinnati and he is in the process of completing a Ph.D. from the University of Illinois in environmental engineering. Darren was hired on by the EPA in 1991 as an environmental engineer with the Drinking Water Research Group. Over the years he has conducted drinking water research in the areas of lead and copper, corrosion control, filtration, iron control, and most recently arsenic removal. With that, Darren, are you all set to go?

Darren: Ready. Thank you. As mentioned by Tom earlier, I'm going to speak about arsenic removal during iron removal. As has already sort of been mentioned by Tom, the adsorptive properties of iron minerals toward arsenic are well known and as a result, many of the arsenic treatment processes that are out there such as coagulation with an iron coagulant and iron based adsorption media as Tom talked about, and of course iron removal, are based on iron surfaces and the importance of those iron surfaces in arsenic removal. I'm not going to go over this anymore and Tom already put this graph up but the point is that we're talking about here in cases of iron removal, you have to have a sufficient amount of iron in the water to remove the arsenic. And, again, this is the thought of iron versus arsenic and we're talking about here in Region A and possibly Region B where we're going to apply iron removal during arsenic removal. And, again,

that plot shows that diagonal line going across at a ratio of 20 to 1, which simply means 1 mg/L of iron is expected to achieve removal of 50 µg/L of arsenic and, again, that's under ideal or optimized conditions and that's also considering that the arsenic is in the Arsenic (V) form.

So we're going to briefly go over iron removal and how arsenic removal takes place during iron removal and this also applies to manganese removal as well for those of you who may not be aware. In the case of iron removal, the first step involves oxidation. Oxidation could be oxidation through aeration, chlorine addition, or maybe potassium permanganate addition. The next stage then typically involves some sort of contact basin and what happens in the contact basin is depending on the oxidant. Oxidation may take place and the iron particles develop and form. Also during this stage, the adsorption of arsenic onto the iron particles takes place and then finally the contact basin is typically followed by filtration of some sort. It might be a green sand filter, it might be a sand filter or some other sort of media based filter system.

Now with regards to iron removal and arsenic removal, what happens to the species through the process? And typically (at least in the Midwest), iron's coming up out of a well as Iron (II)<sup>+</sup> and arsenic is typically coming up as Arsenic (III). During the oxidation step, depending on what type of oxidant is used, typically we'll add our oxidant in the form of aeration or oxygen, chlorine, or potassium permanganate. The iron at this point, depending on how fast the oxidation takes place, will be converted from the ferrous form to the insoluble ferric form or the particulate form, and again, depending on what oxidant, Arsenic (III) is going to be converted possibly to Arsenic (V).

Then during the contact basin step of the process - again, oxidation, particle development, and arsenic adsorption are taking place here and what we have now is an Iron (III) particle with some arsenic adsorbed to it, possibly Arsenic (III) or Arsenic (V) depending on what type of oxidant was used in the step before. Then whatever arsenic is not adsorbed is what we refer to as soluble arsenic and that may be also in the water as well depending on how much iron we have in the water.

Finally then we have the filtration step and the idea here is that we just physically filter the iron and arsenic particles out of the water, that soluble arsenic then is expected to go through the filter, and that will be the residual arsenic that comes out and enters your distribution system. Okay, so now what I want to do is kind of go into some case studies - some field work that we've been involved with here in Cincinnati - to specifically address or examine some of the factors that impact arsenic removal during iron removal and in particular then looking at ways or achieving ways that we can optimize arsenic removal during iron removal with the process that we currently have or one that we may be developing or are in the process of putting together.

The first is a form of arsenic (Tom has already really hit on this) and we can have two possible oxidation states of arsenic - that would be Arsenic (III) and Arsenic (V). Arsenic (III) is removed during iron removal with iron based processes, but it's just not removed nearly as well as Arsenic (V). So depending on how much iron you have in the

water, you could get some removal. Aeration, again, will oxidize Iron (II) to Iron (III) and will get you those iron particle surfaces that you need to have to adsorb the arsenic, but again as Tom mentioned, it will not convert Arsenic (III) to Arsenic (V).

So, here's a case study where a system is using aeration alone. No additional oxidant, so they're not converting Arsenic (III) to Arsenic (V) yet they're able to achieve decent or really good arsenic removals. Basically the system involves a groundwater system here in Ohio that has 2.7 mg/L of ferrous iron starting out in their well. The arsenic level is 0.043 mg/L or 43 µg/L, 80% of which is Arsenic (III). Oxidation simply involves aeration. At that stage, the arsenic again after aeration is still Arsenic (III) and I also wanted to make a note here that ammonia in the water is quite high - it's over 1 mg/L per liter of ammonia. There's no contact basin whatsoever in this system. It goes straight to their filters, which is a sand based material. Again, all the arsenic is in the Arsenic (III) form and again now we have these Iron (III) particles with the arsenic attached to them. As the water comes out of the filters, the arsenic has been reduced down to 8 µg/L so it's able to achieve the MCL of 10 µg/L without having to add an oxidant to convert Arsenic (III) to Arsenic (V). So no addition of permanganate or no addition of chlorine is necessary in this particular system. As a side note though, there is an interesting aspect of this in that the ammonia coming out of that filter is non-detectable and we're beginning to think perhaps that nitrification is taking place within the filter, but I guess the question becomes: Are those nitrifying bacteria capable of converting Arsenic (III) to Arsenic (V) because those Arsenic (III) removals are quite good? So I guess it's an area of research that we're currently getting involved with. But nonetheless, the point is that they didn't have to add chlorine or permanganate or some other strong oxidant in this system.

Okay, in most cases, we are going to have to convert Arsenic (III) to Arsenic (V) to get the ideal or optimum removal of arsenic from the system during iron removal and, again, something hit on earlier: free chlorine, potassium permanganate, ozone, and some of these solid oxidizing materials (the manganese dioxide materials) are capable of converting Arsenic (III) to Arsenic (V). Chloramine, chlorine dioxide, UV radiation and of course, oxygen are not going to do the job for you. So when considering what type of oxidant you're going to use, again it depends on the arsenic and do you need to have it the form of Arsenic (V)? Again, manganese, like iron in many cases here in Ohio for example, is typically in the water as well and manganese is not going to be converted to a particulate form with aeration alone. You're going to need a stronger oxidant just like arsenic. I listed some of the pros and cons of each.

For example, in the case of aeration, if you are able to get by with aeration alone and do not have to convert Arsenic (III) to Arsenic (V), you may need a contact basin from the standpoint that oxidation of ferrous iron to ferric iron sometimes takes time. It could take 20 minutes to an hour depending on the water chemistry. In particular, the pH is particularly important when it comes to oxidation rates of ferrous iron to the particulate ferric form. Again, if we have to address arsenic and manganese, you won't do that with oxidation by aeration. Iron particles, we've found, form from aeration or from the fact that oxygen is oxidizing ferrous iron or ferric iron, have less surface area. They have less

of a tendency or less ability or capacity to remove arsenic and we'll see some data later on that shows that.

On the other hand, we found that, iron particles that are formed as a result of oxygen oxidizing ferrous iron to ferric iron will allow you to have longer filter run times due to the density of the particles. They tend to be a denser particle than a particle formed as a result of chlorination or another strong oxidant. In terms of the strong oxidants like chlorine permanganate, again, these will address the manganese oxidation issues, however, we found from experiments that you run into shorter filter run times. You have to backwash more frequently as a result of using those oxidants because the nature of the particles changes. The iron particles - their nature, their density changes. But, on the other hand, you tend to get and you tend to find that those particles have more surface area and as a result of having more surface area, you're able to remove more arsenic. You have a greater capacity to remove arsenic. Of course, if you have an existing system where oxidation is aeration and you need to add chlorine or permanganate, some of those chemicals are difficult to deal with. You might have safety issues and things like that to consider and probably you won't need a contactor because oxidation with chlorine and permanganate and strong oxidants is rapid, both for iron as well as the manganese and in particular the arsenic. These are very rapid reactions.

Okay, I want to jump into now the importance of oxidation and a case study here in Ohio, a second study where in this case, arsenic levels are between 69 and 132  $\mu\text{g/L}$ , 85% of which is in the form of Arsenic (III) to start. We have iron at 0.5 to 1.4  $\text{mg/L}$  and you can see we also have some manganese in the water and then the pH is approximately 7.9. In this case, what we did is some jar testing and what I'm showing here is the arsenic concentration of the filtered water. That is, the iron particles are formed, the arsenic adsorbs to those particles during the jar test, and we filter those particles out with the arsenic attached to them. So, I've got arsenic plotted on the Y axis versus a dose of chlorine or potassium permanganate on the X axis. The red line here represents the initial arsenic levels of the jars before we start the test and you can see that they're all around 60 to 70  $\mu\text{g/L}$  and what we find in a case where we don't add an oxidant - a strong oxidant in chlorine and potassium permanganate (so in other words, the only oxidant present is oxygen) - we get very low reductions in arsenic: only about 10  $\mu\text{g/L}$ . And again here why we get such low reductions is because again the surface area of those particles is lower, but more importantly, the arsenic is still in the Arsenic (III) form and again we don't get very good removal with Arsenic (III).

But what you can see with both oxidants is that if you increase the dosage of the oxidant, you increase your ability to take that arsenic out until you get to about 2  $\text{mg/L}$  or so of both oxidants and at that point, you've got enough oxidant in there that you can oxidize all the Arsenic (III) to Arsenic (V) and you can oxidize all the iron from ferrous iron to ferric and all the manganese. You basically met all your demand of oxidant in a case when you hit about 2  $\text{mg/L}$  of chlorine or potassium permanganate. So that's an important point - that even if you are trying to oxidize the iron and arsenic with these stronger oxidants, you need to make sure that you have a sufficient amount or you have the residual of the oxidant at the end of the process to get your optimum arsenic removal.

Now, another interesting aspect of this jar test (and then I'll hit on this again in a minute) is that we took the case of the jar where we add oxygen as the oxidant and we oxidize all the iron to iron particles and we didn't get very good removal of the arsenic because the arsenic was still in the Arsenic (III) form so we decided to add chlorine now. So the particles are already formed, so the only thing the chlorine is doing at this point is converting Arsenic (III) to Arsenic (V) and I guess the kind of interesting thing was that as a result of doing that, the improvement of arsenic removal only went from 0.1 to 0.2. In other words, we only achieved another 10 to 15 µg/L of additional arsenic removal.

So, I guess the point here (and I'll hit this again in a minute) is that when you add a strong oxidant, if you have oxidation by aeration already in place, you need to oxidize the iron and the arsenic with a strong oxidant at the same time. If you have the particles already present, and then you oxidize the arsenic later, you're not going to get very much improvement. So you got to move your point of chlorination up earlier before aeration. Again, I'll hit this in a minute.

Here, this is just another example of showing some of the same things that we've already seen. This is some jar tests, this is some batch reactor scale stuff that we've done here in the lab showing a couple of things. The first plot at the top here is showing, basically what I have on the Y axis is filtered arsenic. Again, it's filtered arsenic levels after the iron particles have formed and the arsenic is adsorbed to those particles so it's the soluble arsenic levels versus the contact times in this particular batch scale test. In the first blue plot on the top, we start out with a 100 µg/L of arsenic as Arsenic (V) and what we've done here is we've free formed the particles. That is, we've taken ferrous iron, oxidized it with oxygen, formed the particles, and then added the arsenic. So we've got the particles present, they've been formed, we have the Arsenic (V) and we find that interestingly enough, we get really no removal of arsenic as a result of that. So that just kind of reiterates the previous slide that I showed you that after you've already formed the particles, it's almost too late. You can't oxidize Arsenic (III) to Arsenic (V) because the particles, the surfaces just don't absorb very much arsenic.

The plot below it - the red squares below it - is basically showing the same experiment, but this time we formed our iron particles with chlorine. So we took ferrous iron, added some chlorine, we formed iron particles, then once the particles were all formed, we added our arsenic as Arsenic (V). And, interestingly here, we saw some removal, and it took time, but after about 20 minutes or so we were kind of at optimized with respect to Arsenic (V) removal. We did not get very good removal, only about 40% but nonetheless, it was better than the case of the iron particles formed from aeration - from air. So the point is that the particles are different. Particles forming from oxygen versus particles formed from chlorine have different properties - certainly different adsorption capacity properties with respect to arsenic.

The bottom two plot - the circles - represent the case where the arsenic was present prior to, well at the same time that the arsenic was present, so in other words, arsenic was added. We then added our iron particles or formed our iron particles in the

presence of the arsenic. The blue circles represent the case where oxygen is the oxidant and you can see that when oxygen is the oxidant, you're able to get pretty good removals. Removals dramatically increase. You get about 60% removal of arsenic, and contact time did not seem to make a difference, whereas where the particles are formed from chlorine (which are the red circles down below), the chlorinated particles have a greater tendency to take out the arsenic and you're able to get down to 20 µg/L of arsenic. So about 80% removal as a result of the different types of particles you form from chlorine and oxygen.

Finally, the next example is a case study in Michigan. Again, just kind of reiterating some of the things we've already talked about. This is a study that Tom was involved with that had initially, 19 to 24 µg/L of arsenic, again, dominantly in the initial state of Arsenic (III) - 95% of it. Iron levels were at 0.5 to 0.6 mg/L. Initially the system was set up so that they had an aeration tower with a 20 minute contact time followed by 20 minute contact time then followed up by some pressure filters and then they chlorinated. In this mode, the system basically found that they were able to achieve 50% removal of arsenic. So they're taking all the iron out by converting the iron from ferrous to ferric, filtering it out in their filters, and the amount of arsenic in the form of Arsenic (III) because it's not being converted, here was about 50% removal. So the thinking was we needed to convert that Arsenic (III) to Arsenic (V) and we'll get better removal. So what they did was they moved the point of chlorination up before the filters. So now they've already formed the iron particles through aeration so the water goes through the aerator, the ferrous iron is converted to particles. At that point though, the arsenic is still in the Arsenic (III) form and now you've preformed those particles. They then decide they'll add chlorine at that point and they convert the Arsenic (III) to Arsenic (V), but as we already talked about, since the particles were already preformed, we don't see much additional removal and, in fact, the utility did not see much removal at all. In fact, the removal didn't change. It was still 50% at the end of the filters as a result of moving the point of chlorination up ahead of the filters. So the next step was to move the point of chlorination before aeration. So let's go ahead and let's oxidize the ferrous iron and the Arsenic (III) to Arsenic (V), and ferric iron before aeration. At the same time, like I said before, and as a result of that, they were able to optimize the arsenic removal and improve removal to 75% and as a result of that, they were able to achieve the MCL.

Lastly, what I want to do is just show that we've been doing some additional work with our pilot plant system and this is just showing the rapid mixer, the flocculation, the sedimentation aspects of our filtration system and the point here is, again, to simulate iron removal. Here's our filters and they're dual media anthracite over sand filters and I did want to show you just some preliminary screening data from these runs. We run this pilot plant system at a pH of 7.2 and 1.5 mg/L of iron, run them for several days, and what I'm showing here is just several different runs. Here we include a flocculation basin where we say yes, in other words, that's a contact time contact basin, so whether or not we need contactor, the chlorine, whether or not we're using chlorine or oxygen as the oxidant, whether or not we're using Arsenic (V) or Arsenic (III).

And I guess some of the points here that I just want to make and I guess reiterate the first two data points here that there's the 7 versus the 13 removal. This shows the difference between whether or not you're using chlorine as the oxidant or just oxygen alone and, again, you can get to lower levels if you're using chlorine is what's that showing (the 7 being lower). The second set of data (8/14 and 8/18 dates) is basically showing that we don't have a contactor in place in either one of those runs. We're going straight to the filters. As a result, at least in the case of chlorine, there is no difference. In other words, the contactor does not make a difference. You still get down to 7 µg/L. However, we did observe when oxygen was the oxidant, no chlorine was present. We did not get down to very low levels and that's in part because you need the contact time to convert ferrous iron to ferric iron, so we did not convert all the iron over to particulate form. The next two (8/19 and 8/20) just demonstrate that if you add the arsenic after iron particles are formed, again, you don't get as good as a removal. You can only achieve down to 85 and 48 µg/L. And the final two dates just demonstrate that Arsenic (III) is not removed if we compare those to 8/12 and 8/13 - they're not removed as well as Arsenic (V).

And then the final point I guess I want to make there is that we had differences in headloss buildup in the filters and we had chlorinated particles going on to the filters - headloss buildup was much greater in the case here, as in the case if we had oxygen as the oxidant. And then finally, just some things that we can do to improve the process. We can increase our iron concentration by adding iron to improve the arsenic removal. We can adjust the pH. Arsenic removal's better at lower pH. We can replace some media with adsorption media that would give us some additional benefit and then, as I've demonstrated, change the point of oxidant addition. And then to wrap things up, iron removal equals arsenic removal. Arsenic speciation is important. As I demonstrated, oxidant type is important. The point of oxidant application is important. It impacts both arsenic removal as well as the plant operation and with that, that's the completion of my presentation.

Andrea: Great, thanks very much, Darren. We actually did get a few questions that came in but I think just for the sake of time - we're running just a little bit late - that maybe we can answer them at the end of the Web cast in the last 10 minutes, and if we're not able to do that, then we'll be able to get back to everyone in a written question and answer document that will be coming forth. So I think with that, we're going to go ahead and introduce Abraham Chen and he's going to be giving us an update on the demonstration projects. Now, Dr. Chen is the deputy department manager of the Environmental Restoration Department at Battelle in Columbus, Ohio. He has a Ph.D. degree in environmental science and civil engineering from the University of Illinois at Urbana-Champaign. Since 1997, Abe and his staff at Battelle have provided arsenic research support to the EPA including the Arsenic Removal Technology Demonstration Program under EPA's Arsenic Rule Implementation Research Program. So with that, Abe, are you all set?

Abe: Hello, everyone. I'd just like to give a status update on EPA's Arsenic Removal Technology Demonstration Program. My co-presenter is Lili Wang. Just to

bring up one timeline here, which is October 31<sup>st</sup>, 2001, when the EPA Administrator announced the arsenic final standard as 10 µg/L and the pledge to provide \$20 million for R&D of more cost-effective technologies and technical assistance and training to operators of small treatment systems. And with this one here, we all know that this is the Arsenic Rule Implementation Research Program. Then under the EPA's arsenic removal technology demonstration, there are two rounds. For Round 1 there are twelve sites involved, for Round 2 there are 31 sites. Then for all the demonstrations, we are looking at full scale then also we are looking at long-term demonstration. Then we are focused on the commercially ready technologies and engineering approaches. Then the goal of the demonstration is to determine and document the construction costs and the operation costs of the new system or the modification of the existing systems to achieve the compliance of the 10 µg/L.

In the meantime, we are looking at the new systems process modification of existing treatment for 1 year. Then in the meantime, we are looking for operational and maintenance requirements of the treatment system. Then we look at the characterization of the residuals produced by the process and finally we'll also look at the impact of the treatment process on the distribution system. As EPA looks into the selection of the sites and the technologies using a set of criteria for the site, including location, arsenic level, system size, and water quality, EPA prequalified seventeen sites eventually narrowing it down to twelve sites for demonstration under Round 1. Then for the technologies, EPA went ahead to solicit a technical proposal. Then for Round 1, EPA receive 70 proposals and eventually selected twelve systems for the twelve sites. For Round 2, EPA received 148 proposals and currently we are still in the process of working with EPA in terms of working with the states and the different facilities trying to finalize the selection of the technologies for Round 2.

Then the major activities involved for both Rounds 1 and 2 are demonstration. To begin with, we sit down with all these stakeholders, including EPA, state drinking water officials, facilities, vendors, and engineering firms to come up with and define the roles and responsibilities. Then with that, then we issue a letter of understanding to all the stakeholders. Then after that we go ahead and prepare a study plan. Then we established contracts with respective vendors. Then working with the vendors and the facilities, we work with the state to obtain required permits. Then after the system is installed and being professionally shaked down then we go ahead and have 1-year sampling for the demonstration. For the sampling, we do weekly sampling and monthly speciation and we trained the system operators to collect all the samples for us so that the samples may be shipped back to Columbus to Battelle's headquarters here for the analyses. Then with that we also prepare progress reports for EPA and prepare reports for the other purposes and finally come out with the 6 month report and the 1-year final report.

The next slide here shows the states that got involved. Essentially here we got twelve sites in nine states. For New Hampshire, New Mexico, and Arizona, we have two sites each for each state. Otherwise the rest of the states here have just one site each. This is for Round 1. Then for nine states, each state will have one to two sites and then all of these are the community water systems. We do not have any non-transient, non-

community water systems for Round 1. Then for the multi-component sites, we have only one, which involves arsenic and nitrate. For the size of the system, it ranges from 37 to 640 gallons per minute. Then for the technology selected for Round 1, the adsorptive media systems there are nine sites involving four adsorption media. That's E33, GFH, G2, and AAFS. Then we have one location using ion exchange to remove both arsenic and nitrate. Then we have one location involved with iron removal using Kinetico's Macrolite process. Then finally we have one location that just has the system modification.

Then the next slide here is a summary of all the sites including the ones listed here and also in the third column here are the technologies tested and also the vendors. And it's interesting to note that for arsenic concentrations for instance now ranging from 14 to 146 µg/L, for some of the states in the east and also in the Great Lakes area, most arsenic is in the form of Arsenic (III). Then meanwhile, with most of the water that has Arsenic (III), we also have a fair amount of iron and that also stays as a soluble iron as a reduced form. Then for the water in several cases, while we have pH values as high as 8.2 and 8.5, for instance, here in Nambe Pueblo, New Mexico.

Then for the nine adsorption media systems here, the G2 media is being tested out in Bow, New Hampshire and the system has two vessels and it's configured in series and the vessel is constructed of extended steel and the media volume per vessel is 85 cubic feet. The EBCT and the design flow rate is 18 minutes. For the E33 systems, this is by Severn Trent. Two of these systems have two parallel units. The other one's here for Brown City. We have two systems, including two parallel systems eventually being combined to treat the 650 gallons of water per minute. The media per vessel is 80 cubic feet and the EBCT for each vessel is 3.7 minutes. For the E33 system by AdEdge, at these three locations at Nambe Pueblo, Rimrock, and Rollinsford, two of these systems are arranged in parallel and one in series. All of these vessels are fiber reinforced plastic and then the media volume is 27 cubic feet with EBCT right around 4.2 to 4.5 minutes. For GFH (that's by US Filter) and this is at Reno, Nevada and we have three vessels, arranged in parallel with carbon steel constructed vessels. Each vessel has 80 cubic feet of media with EBCT of 5.1 minutes. Then finally this is AAFS media being tested out in Valley Vista, Arizona - two vessels in series with EBCT of 4.4 minutes.

Then in some cases the system will have some pretreatment. The pretreatment here includes primarily chlorination and/or pH adjustment. There are two major purposes of doing chlorination - one is to convert Arsenic (III) to (V). The other one is to disinfect or to prevent the biological growth. For the pH adjustment, clearly we tried to adjust the pH down from 8.2 or 8.5 to right around 7 using either sulfuric acid or carbon dioxide. Then in several cases, if prechlorination is not being done, then we have a postchlorination here to provide the chlorine residual. For Round 1 status here, so far we have eight systems operational and one system under the iron addition testing, which is Lidgerwood, North Dakota and then we have one system already installed but currently we still have some problems in terms of trying to get water past the bac-t test in Fulton, Idaho. In the meantime, we have two more systems still to be installed and tested, hopefully, by the end of year which are Nambe Pueblo and the Reno, Nevada site.

We have a few photographs here to show the systems here. These are the Severn Trent APU-300 systems. 300 here means 300 gallons per minute. And this system here is the Desert Sands system at Anthony, New Mexico. The vessel sites here are 63 x 86 and these two vessels are arranged in parallel. And this system here is in Stevensville, in Queen Anne County in Maryland, again, this system is very similar to the systems at Anthony/Desert Sands, New Mexico. For Brown City, as I said before, that we have two sets of these systems. Each one has the capacity of 300 gallons per minute and all these vessel sites are similar. For APU-100 systems, at the Rollinsford site, because the water pH is right around 8.2 we are using carbon dioxide to reduce the pH from 8.2 to right around 7. These two vessels are currently arranged in parallel and this is the original pumphouse and this is the building that houses the equipment. This system currently is being installed in Bow, New Hampshire. These two vessels are constructed of extended steel and the media here is a G2 manufactured by ADI.

The next system here is being demonstrated in Valley Vista, Arizona. The media is AAFS 50. That's manufactured by Alcan and the flow rate here is 37 gallons per minute. The vessel is arranged in series. This is the system in Fruitland, Idaho. These are the ion exchange vessels and this system is in Climax, Minnesota. These two vessels are the contact tanks and after the 5 minutes of contact tanks, the water is treated through this pressure filter using Macrolite media.

Finally, this is a system where we were doing the system modification. We are studying the water chemistry trying to reduce the soluble arsenic concentration to less than 10 µg/L. In the meantime, we are trying to see if there's a need to change the current filtration media, which is the manganese dioxide coated sand. We're going to see if there's a need to change it to other media such as Kinetico's Macrolite. What it's showing here is in order to look at water quality, we have a set of turbidity meters and also we look at the pressure differential to one of the four vessels of the filtration cells. In order to reduce the soluble arsenic concentration to less than 10 µg/L we are adding some ferric chloride into the water. Before the addition of ferric chloride, the best the treatment facility can get is about 30 µg/L of arsenic and based on our latest data, it appears that we'll be able to reduce the arsenic to less than 10 µg/L.

This is just a summary table here to show the waste disposal. There are usually two types of waste that will be generated by these treatment processes; one is the spent media and the other one is the backwash water. After media is spent, then it looks like the media (in most cases, and so far we know that it is in all cases) can be tested to pass the TCLP test for the disposal. Then for the backwash water here. In most cases, we're talking about 10 to 15 bed volumes of bed water that get produced with every backwash cycle and then the frequency of the backwash really depends on how much the solids is intercepted by the filtration media. Now, in terms of the backwash water disposal, it can go into some kind of a surface leach field, some holding pond, some ditch. In one case, it also is being hauled away for offsite disposal. Otherwise, the wastewater can also be disposed of into the sanitary sewers.

The map here shows the Round 2 states. Essentially, we have 31 sites in nineteen states. These are the sites selected by EPA for Round 2 demonstrations. We have five in the East and Northeast area, ten in the Central Midwest, six in the Midwest area, and ten in the far West area. The current status is that for the nineteen states, the 31 sites, the number of sites per state is about one to three and we have 28 community water systems and we have four non-transient, non-community water systems and then in terms of the multiple contaminant sites, we have four, including contaminants such as arsenic, uranium, and nitrate. The sites range from 7 to 600 gallons per minute.

The differences between Rounds 1 and 2 here include the four Round 2 NTNCWSs. Then also we include some POU and POE approaches for the demonstration. Then also we have multi-contaminant treatment systems. For Round 1 there was only one - we had Fruitland that would treat only arsenic and nitrate. For Round 2 we have several other contaminants involved. The Round 2 technologies that currently are being considered and selected include all these technologies listed here. Then the status level of Round 2 demonstration: so far we've been working with the EPA - Tom and Darren - to visit nineteen sites then out of these nineteen 9 sites, we have conducted five return visits for planning the project to define the roles and responsibilities. In the meantime, out of those five sites that we have issued a draft letter of understanding to all the stakeholders. With that, this is the end of this presentation.

Andrea: Thank you, Abe. I think we had one question that came in. It was basically dealing with how were these facilities chosen. We have a system that produces arsenic at .0958 mg/L. So I think what they're trying to get at with these different demonstration systems that were chosen (and I think you speak to that in Slide 5 and the selection process and Tom Sorg might be able to answer this as well), but I think basically their question is: "how did these sites get chosen?"

Tom: Andrea, I should probably answer that. The first thing we did is we asked for sites interested in the project to submit information to us and between Round 1 and Round 2, we received approximately 200 systems that expressed interest in working with us. When we selected the sites, there were three major factors that we considered. There were some others, but they're probably the three major ones. Number one, we wanted to make sure we had a good geographical distribution. We weren't going to put them all in California or Arizona. As you can see, we've got them spread around the country.

The second factor was the arsenic level. We gave higher priority if the arsenic was high, 50 µg/L than if it was near the MCL of 10 µg/L. So, if all things were equal, and if a site had 35 or 40, we thought it was a bigger challenge than if the site was only 9 or 10. And then finally - and this has to deal with because of the cost of the systems, of course, the bigger the system, the large the flow that you have treat, there's more money involved in purchasing the system - so, once again, all things being equal, we looked for smaller flows rather than larger flows. We had a number of systems that came in wanting to treat flows of 1,500 gallons a minute and that would have eaten up most of our funds. So as you can see, in our program, at most of the sites the flows that we're treating are generally less than 200 or 150 gallons per minute. There were other water quality factors

also involved, but those are probably the major criteria that we used for selecting the sites.

Andrea: Great, thanks, Tom. I think we'll go ahead and just switch gears a little bit and go into our panel discussion. We're going to be talking about the Valley Vista and Rimrock demonstration sites in Arizona that were chosen during Round 1. We thought it might be interesting to talk to some of those folks who have been directly involved with these two systems to give people throughout the country an idea of what they may be facing and have already faced in trying to get treatment in place for arsenic. And granted that it's going to be different all over the place, different systems, different situations, different source water characteristics, but I think this kind of gives you a good sense of what's going on and what it takes to get a system going. So we'll have Tom Sorg as part of the panel discussion along with Lili Wang from Battelle and then Bill Garfield from the Arizona Water Company. So I think what I'd like to do first is just start out by having each one of you explain just a little bit what your role has been with these two systems and I guess I'll just start out with Tom.

Tom: Well, of course, these two sites in Arizona were part of Round 1. We selected the two sites in Arizona based upon the criteria mentioned before. After we selected the sites, then we went out to the engineering and vendor community and asked them to submit technical proposals. And they had to submit a proposal for each specific site. And in Round 1, we had anywhere from only one proposal submitted on a site to, I think up to six. EPA then convened an expert peer review panel who reviewed the proposals and their role was to really give us recommendations on which technologies they thought were ready to go to full scale demonstration. This is full scale. We're putting these systems in. The water's being treated and going out into the distribution system. So, some companies were submitting proposals on technologies that was very apparent that they still needed to do some research. It hadn't gone much beyond the bench scale research phase. That process narrowed down the proposals. It probably eliminated about 50% of them.

After we received their recommendations, then we went out to the site and we sat down with the utility and the state agency, reviewed the proposals, and then made our selection and the determination or the selection of the technology was a mutual decision for the most part between EPA, the water utility and the state agency. Now, in the case of the two sites in Arizona, if I recall, and Bill may want to comment, they were really looking at the same technology for both sites. They were both adsorption technologies and in this case, we did push one site to consider a different type of adsorptive media. So one site has the E33 media. The other one has the Alcan modified activated alumina. We did not want to demonstrate two identical technologies in the same state and the two are fairly close to one another. So as a result of our meetings with Bill, we ended up with those two technologies.

Andrea: Thanks, Tom. Now, Lili, then what kind of role have you had with these systems?

Lili: Well, we work with Tom Sorg to oversee the site demonstration activities. We kind of lead all the planning activities and work with the vendor and the site to go through all the permitting processes and then after the system is installed, we also conduct the training for the operator on the data and sample collection and also we review the operational and analytical data, maintain the operating logistics, and track the project progress, and then eventually we're going to prepare a 6 month report and also a final report to summarize the performance of the technology.

Andrea: OK. And Bill you're with Arizona Water Company. Why don't you talk about your role and then maybe just give a little bit more of an overview of the systems themselves in terms of the populations served and some of the arsenic levels.

Bill: Sure - I've worn many hats in this. One was coordinating our personnel for the onsite monitoring and operation of the plants, but also was coordinating some of the site preparation, some of the things we had to do in advance of the vendor being able to install their facilities onsite. Another role that I played was working with the state agency to determine what is an adequate monitoring program to ensure that public health is protected because these are demonstration facilities that are producing water for our consumers. So we worked with the agency to come up with a monitoring program and that would ensure that public health is protected and also provide technical data for the state agency to review and to determine whether this plant will operate on a going forward basis. So those are the primary roles that I played.

The systems themselves -Rimrock is a small system located about 90 miles north of Phoenix. A little over 1,100 customers, population around 3,000. It's totally a groundwater system. Relatively small wells—50 to 300 gallons per minute. Arsenic levels ranging from just under 40 to just over 50, so fairly high. Valley Vista is about 25 miles northwest of Rimrock in an area called Oakcreek Village just south of Sedona, Arizona, a little smaller system. It's around 700 customers, population of around 1,500. Similar well capacities from probably the Valley Vista well, which is 37 gallons per minute to around 200 or 250. Arsenic levels slightly lower from 35 to 45. That's it for the systems.

Andrea: Okay. Great, Bill. Maybe you could just go on and talk about maybe some of the hurdles that you had to face along the way. I think you were talking about some of the state interaction you had before, some of the technical reviews.

Bill: I'll address it from our perspective. For the state agency, the Arizona Department of Environmental Quality had to review the plant for the construction and the operation of the plant and until recently there haven't been many arsenic treatment plants built in Arizona. So this was a little new for them to review and the technologies were relatively new. They were not the longstanding technologies, so the E33 product was a little new for them and it took a little coordination through the agency to have them become familiar with that. The secondary issue was: here is water that's going to be produced from the plant - what frequency of monitoring will we need and for what length of time? And also sort of dovetailing that process control monitoring with compliance

monitoring. So that took a little bit of the discussion with the agency and it probably took several weeks or so to get all parties to agree what the monitoring should be in addition to whatever monitoring EPA or Battelle was wanting in order to determine the feasibility of the technology and so forth. And I should mention there is a considerable amount of time needed to work with a demonstration plant, but even with that time involved, I can tell you that all of our system operators have found it to be a very good experience.

Andrea: I think I remember you mentioned at some point that the operators really had to spend some time going through training for this new technology.

Bill: That's correct. Most rural parts of Arizona that use groundwater, other than chlorination, many of them do not have any form of treatment. So for them it was - even though many of them are qualified treatment operators - this was a new thing for them. Very exciting for them to be involved and learning how to use the portable arsenic test kits and gathering samples and coordinating this with Battelle and others was, you know, there was a lot to do and it was a lot of coordination between our system personnel and the EPA contractors and the vendors. So, it worked out very well.

Andrea: Speaking of contractors, Lili, I think Bill had mentioned in terms of performance monitoring, well you had to do all the performance monitoring and I believe you also had some issues of permits or just the cost of some of the state involvement. Maybe you could talk a little bit about that?

Lili: Yeah, sure, Andrea. Yeah, I'd like to share our experience with this permitting process. Essentially, this is kind of a three step process. First of all, we assembled the engineering plans and submitted them to the Arizona Department of Environmental Quality for approval to construct and that process took about 5 to 10 weeks to get. The first one for Rimrock, it took a little bit longer. That's 10 weeks and also because that's during the holiday season. For Valley Vista, it only took 5 weeks to get that approval.

And after we got that approval, we applied for a construction permit to the county and that process took about 2 to 3 weeks to get. And once we got the construction permit, we went ahead to install the system and do the shakedown and startup and before we connect the water to the distribution system, we had to get another approval of construction. Basically, we had an engineer who saw the actual drawings and also we took the samples for bacteria tests and submitted the results to ADEQ again for the approval of construction and that process normally should take about a week to get, but for Rimrock and Valley Vista, it took us about 2 to 4 weeks to get that approval. So, as you can see, it's a little bit of a time consuming process, but I think one thing that we can do to expedite the permitting process is to get the state people involved at the early stage to get them familiarized with this new technology to give them some background information so that way I think it will work out just fine.

Andrea: Sounds good. I guess I'll have to go on to the million dollar question. How successful has the treatment been so far?

Lili: Well, depends on how you define its success. In terms of removing arsenic, both technologies worked pretty well. To give you some data, for example, for the Rimrock system that used the E33 media (that's iron-based media) and both systems started operation around the end of June this year. As of October 6, after treating about 2.3 million gallons of water or 12,000 bed volumes, the B tank in Rimrock right now has about an arsenic breakthrough of only 2.1 µg/L and the last tank, the polishing tank, only has 0.4 µg/L of arsenic in the effluent. And the influent arsenic has about 48 to 80 µg/L. And the other system, the Valley Vista, that used the alumina based media, that's AAFS 50. After treating about 6 or 7,000 bed volumes of water, the lead tank had an arsenic level of about 10 µg/L and then the second tank treated about 13,000 bed volumes before the effluent concentration got to 10 µg/L. So we think that both technologies can definitely remove arsenic to below the MCL, it's just a matter of how long it's going to break through and how often you need to replace the media.

Andrea: That's great. Thanks Lili, for that information. Does anyone have anything else to add before we go on? We only had about 15 minutes for this panel discussion, so I don't want to eat into the next presenter's time. Is there anything else anyone would like to add?

Bill: Just that it's been a good experience.

Lili: Well, maybe I would add a little bit about how we conducted performance evaluation study. We developed a study plan to kind of describe our technical approach in terms of how to collect samples and data. We asked the operator to fill up the daily field log sheets that record the system's operational data such as flow, pressure, and the chemical consumption. And also we sent the sample coolers to them once a week, asked them to collect samples from the raw water and after each tank and also from the distribution system. So that's on a weekly basis. And every month, we ask them to do the outside arsenic speciation, so we know whether there's any Arsenic (III) in the raw water. Other than that, we also analyze the sample for some water quality parameters such as alkalinity, fluoride, sulfate, nitrate, also phosphate, silica, turbidity and those kind of water quality parameters and we also trained the operator to do the outside measurements using a water meter. For example, to measure the pH, temperature, dissolved oxygen, and the redox potential and also free chlorine. We collect all this data so eventually we can evaluate the performance of these technologies.

Andrea: Thanks, Lili. Looks like there's obviously been a lot of work involved, but it sounds like there's been great coordination. I'd like to thank all the panel members - Tom, Lili, and Bill - for taking part in this. We probably should go on to Bernie Lucey's presentation. Bernie has a B.S. in civil engineering and an M.S. in sanitary engineering from Northeastern University in Boston. Mr. Lucey is a registered professional engineer in the state of New Hampshire and a member of the New Hampshire, New England, and American Waterworks Associations. Mr. Lucey has worked for Boston-area consultant engineers and since 1973 for the New Hampshire Department of Environmental Services. He has also been a member of adjunct faculty at

the University of Massachusetts at Lowell from 1980 to 2002 teaching courses related to water distribution and treatment. Mr. Lucey is the New Hampshire lead for arsenic and was a member of the EPA peer review committee for the EPA design manuals on removal of arsenic from drinking water by adsorptive media and ion exchange. So with that, Bernie, are you ready to go?

Bernie: I am and I hope you can hear me.

Andrea: I can hear you.

Bernie: That is great. Well, good afternoon from New Hampshire. We are sort of a northern suburb of the Red Sox nation. I needed to say that for my other staff members here in the agency. Let's begin by looking at the arsenic problem as it exists in New Hampshire. It's very much oriented to very small systems. Those systems are typically using a bedrock well. That's where the arsenic is - typically 300 to 700 feet deep. Average of 50 to 75 units, 150 customers approximately. Typical wells are maybe 20 gallons per minute as an average.

Of the total number of community systems we have (about 700), ten are currently treating for arsenic. Essentially all of them are using adsorptive media. That media, up until a year or two ago, was activated alumina and now as the sales reps for the other new products make their rounds, some people are rebedding with other medias and trying those out and so we're just starting to gather up really detailed information as to how many bed volumes we can get with each type of media on a typical New Hampshire system. We expect about a hundred more systems will need some form of arsenic treatment - and I think for the most part, it's going to be treatment as opposed to say flow mixing - and those systems obviously have arsenic between 10 and 49 parts per billion.

On the non-transient side, we have about seven systems right now with treatment and that treatment is sort of a hybrid. We have allowed systems to put in a dual distribution system and that would consist of a treatment process as the water comes in through the foundation and a secondary plumbing system after the water treatment process, which would deliver treated water, in this case, without arsenic, to various drinking water fountains throughout either the school or workplace. We have about thirty more of those systems that need to do something over the next 18 months or so.

We are fairly lucky in New Hampshire relative to some of the competing ions that are somewhat problematic with most adsorptive media. We have very little silica, phosphate, vanadium, sulfate, and generally iron does not co-occur with arsenic in New Hampshire. It's not a competing ion, but it certainly would gunk up most media filters. We're lucky not to have that. We do think that adsorptive media is going to be by far the approach that most systems use. So, some New Hampshire policies are a little laxer than the average in terms of drinking water systems. We do not require professional engineering on water systems that serve less than 1,000 people. Generally, small engineers we found out don't really have much experience with drinking water treatment.

That consequence throws the ball to us in the program to be much more hand holding and much more affirmative action oriented in getting a new program like this off the ground.

For pilot studies - I know your title talks about pilot studies here in New Hampshire. To some extent we did those a few years ago, very fleetingly. We now have reasonable confidence that adsorptive medias are going to work well across the board in New Hampshire. The geology of New Hampshire throughout its entire footprint is pretty much the same and so we know the factors that would create a problem and fortunately those competing iron factors don't appear to be commonly occurring.

The empty bed contact time issue I think is quite critical and it's going to be an area that we're going to offer comment when we are going to design that chooses one of the medias. There's a couple of medias that are very rapid action and, consequently, the size of the treatment canister can be quite small. In a pump facility that doesn't have much floor space, that may be a real asset, but it certainly ties that particular water system to using only that proprietary product and we're going to suggest that most people consider a tank size that would allow, say, 5 minutes or so of empty bed contact time.

Variations, exemptions. We don't expect any variations. I think so far every utility that has tried arsenic treatment, it's been successful. It's successful even in the stance of the new and tighter standard. In terms of exemptions, we would certainly entertain an exemption request for something like a regional water district, but we don't think any of those are likely.

The last item on this particular slide: radon floor space. We have substantial radiological problems here in New Hampshire and we're going to be asking each utility to look at the floor space requirements for radon treatment and also for uranium treatment in order to make sure that they don't squeeze an arsenic treatment system in now and then find out that they have to totally or significantly rebuild just say a year or two from now on uranium and 3 or 4 years possibly if the radon standard ever gets finalized. So I'm going to try to make this a rather broad evaluation for some of the other factors that are going to effect very small systems.

So, the way we started out in terms of implementing the arsenic new and tighter standard was to first develop from our existing laboratory data a short list of systems that were likely going to have a compliance problem and we formatted that in part in a mailing list format and we have provided that readily to sales representatives from the various media companies so that they can go out and basically help us to partner with us and help utilities to know what the problem is, what the time frame for that problem solution is and to at least put one option for solution in front of those particular utilities.

We also used that mailing list to identify many educational programs that we've had on arsenic in the last 2 or 3 years and we notified each of our utilities of the Arsenic Demo Project. Obviously in hindsight, that was a good idea because we have been most fortunate to have three of those sites located in New Hampshire.

Arsenic speciation, that is not a laboratory process. So many people, once they slightly know about arsenic species, they think that it's a laboratory process. It's really a field collection process and we have purchased two anion exchange cartridges, approximately 3 inches by 10 inches that go in typical sediment cartridge housings and those cartridges we loan out to utilities so that they can do a rudimentary speciation determination on their particular supply sources. Utilities appreciate that and it certainly drives home to the operators the importance of species identification.

The slide in front of you now shows this species setup. It is the most simple thing ever. It's just a whole series of three pieces of rubber hose, a throttling gate valve, a wall water feed from the supply source. We do not do a filtration setup at this time or filtration effort. We just run the water through an anion exchange cartridge, basically ask the utility not to run anymore than a couple of gallons through this because we don't want to be buying cartridges left and right and so I've put together a little example here. So if you look at this schematic, a species determination would consist of two samples. One sample that would be treated through the arrangement that you see on the screen and a second sample that would be raw water. Now, let's look at the very bottom of the slide that is on the screen. Let's assume that the total arsenic in this particular example was 35 parts per billion and that the water that came out of the right hand side of that arrangement that you saw had an arsenic level of 15. That 15 parts per billion would be the amount of Arsenic (III) because essentially by definition, Arsenic (III) will not treat at all using anion exchange resin and then if you do the subtraction process, 15 subtracted from 35, that gives you the amount of Arsenic (V) in the sample, which in this particular case was 20 parts per billion.

Knowing that we are not going to mandate that people preoxidize, we're going to suggest that they do it, but if they don't want to, many of the medias will adequately treat both valence (III) and valence (V), but you get certainly better longevity out of a system where all the arsenic is in the species (V) format and I think it's worth the effort to preoxidize, but at the moment we're not requiring it.

So, let's go on to the next slide, "Reducing the Fear Factor." We have, as you saw in the first slide, probably 130 systems that need to act and it is really slow going. Why? Because I think there's a fear factor that this is both a health issue and also they're aren't too many facilities at the moment where people can develop a confidence level in moving forward. So we have developed a list of all the medias that are currently available and at least the ones that we know of. We have a few more to add to that list. That list is on the reference information that is part of this Web cast and you'll see that as an appendix to my presentation. You will see the names of the various suppliers, contact information, and some signification attributes on each of their media's characteristics. We need a little bit more time to make perfect that presentation. I'll have that available in another month or so and people are welcome to contact me at the email address which will be given at the end for an updated copy of that.

In the second issue of reducing the sort of fear factors is tours of existing systems where each of these 15 or 20 systems that currently exist, we have developed a detailed

description of the size of the facility, the number, the amount of arsenic, the pH, other factors, including what media they're using and we make that available to people that would like to go as a group to that existing system or to visit that existing arsenic treatment system on an individual basis. We haven't done too many of those groups yet. We're planning that as an activity this winter when we get otherwise snowed in.

Interaction with EPA. We have spent a lot of time working with EPA and Tom and Darren and others on the arsenic design manual and around the year 2000, Lili and others from Battelle came to New Hampshire here and we happily reviewed two existing arsenic treatment systems that were very well designed, very well sized and those reports are in various documents that you may have been referring to earlier, which I hope are called out on the Web site. In addition, we have the arsenic demo project. We had an open house in one of those just a couple days ago and the other ones will be the focus of waterworks meetings and other presentations over the next year.

Evaluating media. I'm basically suggesting to people that they shouldn't have a fear factor. They should just jump into it, get something accomplished now before January of 2006 and if bedding medias come along in the future or if some of the other medias that are already out there were not tried, those medias can be evaluated during the first operation session with whatever media they first choose and that by a small little 3 by 10 cartridge pilot study they can determine with nothing more than the expense of doing a few arsenic tests, what the cost effectiveness or the bed volume effectiveness is of one media versus another versus another. And then at the time that they need to rebed, decide whether they want to make a change to a different media and try that out for their second bedding of their treatment process.

This little mini pilot system for evaluating the cost effectiveness, and cost is the key word here, of various absorptive medias as shown on the slide that's currently on the screen. The only way that differs from the previous slide is that a water meter's been added so you can determine bed volume capability. In terms of design criteria, we generally are talking to systems and not strongly recommending that they try to develop another alternative water supply in New Hampshire. That would be staying up in the sand and gravel soils and developing a well in that material because that material typically does not have any arsenic in it, but that might be something that one utility might find favorable because of the favorable water resource availability. Secondly, the bureau is suggesting a series configuration and strongly suggesting that and so far most of our new systems are of the series configuration. Tom very nicely gave some of the attributes of the series configuration and it's the way that it should repay itself. It certainly is a little more expensive up front, but it should repay that additional capital cost by long terms savings and media. We do suggest preoxidation of the water before it gets to the media.

Spent media removal. I have seen a few repetitions now of removing media from tanks, be they fiberglass or stainless steel, it's a somewhat laborious situation. If you have a sidewall port, it's a lot easier to let the media fall out of the manway that would be in the sidewall of the tank, but on really small fiberglass tanks, I don't think they're going

to make them with sidewall ports. If you're going to come in from the top, you're going to need significant head room, at least 4 to 5 feet between the top of the tank and the underside of the ceiling and hopefully people remember to accommodate that measurement.

Andrea: Bernie? I hate to interrupt you, but you might want to move to the last few slides a little bit quicker. We want to give Janet a chance to speak.

Bernie: I think we're essentially there. We're going to drop the technical approach to the industry soon in favor of sort of tough talk relative to meeting the standard by January of 2006 and finally at every opportunity we have, we note that in dealing with the public media, TV or newspapers, we also mention arsenic in terms of how it spins for a private well facility because we have a major effort there in private well outreach. So I thank you very much.

Andrea: Thank you, Bernie, we really appreciate it. Good presentation. Because we are running a little behind, we are just going to go on to Janet Cherry from The Cadmus Group and Janet has an engineering degree and is a registered professional engineer. She's worked in the water industry for over 15 years in both the private and public sector. She is a former Montana drinking water employee and currently works for Cadmus in the Helena, Montana office. So, if you're ready, Janet?

Janet: Yes, I am, Andrea. How much time do I have?

Andrea: Go ahead and present. We may run out of time for questions, but again, if we don't get to the question and answer period at the end of this Web cast, again, we'll provide written answers to all the questions after the Web cast some time. So go ahead and present.

Janet: OK. Great. Thanks Andrea and greetings from Helena, Montana, where we have snow on the ground this morning. And, of course, we have no particular affiliation to any of the sports arenas like Bernie does. With that, we'll get started. We've heard a lot about the arsenic removal technologies and now we'll examine the residuals created by the arsenic removal technologies and disposal options that may be available. As the water system considers disposal options, the water system must analyze the residual to determine if it's non-hazardous or mixed waste. I'll define these terms throughout the presentation. The characteristics of the residuals will depend on the raw water contaminant concentration, the treatment process that's used, and the operation of the treatment process. It's also important that the water system understand all federal, state, and local regulations and the permits that may be required for each disposal option and as the system looks at the residual disposal options, they will be different for liquid versus solid residuals.

Like I said, the arsenic treatment processes, they're will be liquid and residual streams. The liquid streams can consist of brine, backwash water, rinse water, acid neutralization water. These four liquid streams would result with anion exchange

process, the backwash water will be a liquid stream generated during backwash of any adsorptive or granular media. A concentrate will be realized with use of reverse osmosis technology, the reject stream that's created as the water passes through the reverse osmosis membrane.

As far as solids go, there'll be spent resins. These could be your spent anion exchange resin. Spent filter media. This will result if the system's using granular media filter or an adsorptive media. Spent membranes - it's when the RO membrane reaches it's useful life - those membranes need to be disposed of - and sludges. So, for instance, during the backwash process if there's some settling and sedimentation of the backwash water prior to disposal, there'll be a sludge created that the system needs to consider along with the liquid as the sludge is dewatered.

Here's just a quick example of an anion exchange process as some of the liquid residual streams that will be created as the anion exchange bed is regenerated. There'll be a regenerate stream that's created. A backwash stream and also a rinse water that will be regenerated. The characteristics of each one of these individual streams during the regeneration process will be quite different. So it's important that the water system understand the concentrations of arsenic and co-occurring contaminants in the residual streams during the regeneration process and that will factor into the disposal option available.

As far as waste identification. Again, it is the water system's responsibility to analyze the residual stream and determine what type of waste they're working with. If it's solid or liquid. If it's a solid, as far as disposal goes, the system will have to do a paint filter test to determine if there are free liquids present. To determine if the waste is hazardous or not, the main test is the toxicity characteristic leaching procedure, or the TCLP test, and for those of you in California, there's another test that needs to be performed - a waste extraction test. And then another category of waste that might occur is mixed waste and this is when the waste is both hazardous as determined by the TCLP test and if the waste contains more than 0.05% uranium or thorium by weight so this might be a problem for those systems using a technology such as anion exchange that removes both uranium and arsenic.

So what tests does the system need to perform to determine if the waste is hazardous or not? These are regulated by RCRA, the Resource Conservation and Recovery Act, a federal regulation, and first the system will do a paint filter liquid test to determine any free liquids and then the TCLP test is performed and under TCLP, there are metals and organics that are regulated. Arsenic is one of the eight metals regulated under RCRA and the current limit under RCRA for arsenic is 5.0 mg/L. So if under the TCLP test if the arsenic concentration in the leachate that is produced as part of the TCLP test is greater than 5.0 mg/L, it will be determined hazardous and please make a note that the limit of this 5.0 mg/L in RCRA is not tied to the arsenic MCL set forth in the federal drinking water regulations. These are two separate regulations. So, when the new arsenic limits take place in January 2006, it will not effect the RCRA regulations unless somebody goes back in and changes the limits in RCRA.

The paint filter liquid test, I've mentioned that. It's to determine if there's any free liquid present in the waste. Waste containing free liquids are banned from disposal in municipal solid waste landfills and hazardous waste landfills. The concern with free liquids is that they could migrate and contaminate any nearby groundwater or surface water in the vicinity of the landfill. The liquid waste that may be contained in the solid waste must be disposed of too, so if there's dewatering of your sludge or your media after the media has reached its useful life, the water system needs to consider the disposal of both the media or sludge or solids and then the liquid that's created.

The TCLP test, the toxicity character leaching procedure, predicts if hazardous components of a waste are likely to leach out. Under RCRA, there are eight metals and 32 organics and again, arsenic is one of the eight metals regulated and if you exceed any of the limits as established under RCRA during the TCLP test then your waste will be classified as hazardous and the system must consider special disposal options.

I've mentioned mixed waste. Again, mixed waste is when the waste has been determined to be hazardous as done under RCRA and the TCLP test and contains more than 0.05% uranium or thorium by weight, then you have mixed waste and you're into a whole different set of licensing and disposal of that waste. Here's a list of disposal options for liquid residuals. Again, those are brine, backwash water, rinse water, acid neutralization water and concentrates. The water system could discharge directly to a surface water body. This would require a permit an NPDES permit and then there would probably be some pretreatment involved in order for the water system to do this. Another option is to discharge to the publicly owned treatment works or the wastewater plant. There will be a permit required and some pretreatment in order to make sure whatever the water treatment plants into the POTW does not cause any interference or violations of permits that the POTW has.

There's also an issue with TBLs - that's technically based local limits - that the POTW must meet. They're imposed by local regulations and, again, so whatever the water treatment plant sends to the POTW it can't cause any problems or upsets at the POTW. Another option for the liquid residuals is injection into a Class I underground injection control well. And this type of injection well will accept hazardous, non-hazardous, and mixed waste but a permit is required. It could be quite expensive and the last option there on the screen is injection to a Class V UIC well. An example of this might be taking the liquid residual to a septic tank and drain field and it's probably an option only for our smaller systems generating a small waste stream.

For our solids, there's landfill options and depending if the waste is hazardous or not, there's two types of landfills. Again, any time you go to a landfill, there can be no free liquids present in your solids and the landfill owner always has the option to refuse any waste regardless of whether it's hazardous or not depending on what type of landfill you're going to so it might be worth communicating with the landfill prior to considering this as a disposal option and then if you have mixed waste, there's only a few landfills in the country that will take mixed waste.

Again, the water system needs to be aware of intermediate processing of the residual. So, for instance, if there's sludge, there'll be some dewatering prior to disposal and every time you do another process, intermediate process, you're creating another waste stream that requires consideration for disposal. So, in closing, I just would like to remind everyone that the raw water characteristics, treatment process, and operation of the treatment process will effect your quantity and quality of residuals and it is the owner of the water system's responsibility to test and make sure what type of waste they're creating and if it's hazardous or not. So I think that sums it up. Thanks, Andrea.

Andrea: Thanks, Janet. Really appreciate the presentation. We are just about out of time and I do apologize that we're not able to address some of the questions that came in. There is some really good questions. Unfortunately we went over a little bit in some of the presentations, so we will get back to your questions and we will provide answers and post them on our website as we have in the past with the Radionuclides Web cast. So look for those in about a month or so. I'd like to thank everyone for attending today's Web cast and I hope you were able to glean some useful information here about the various treatment technologies and what seems to be working and logistics of setting up some of this new technology and also some of the pitfalls you may encounter. I'd also like to remind everyone of the next arsenic rule webcast scheduled for December 1<sup>st</sup> from 2-4 Eastern Time. This Web cast will focus on an overview of rule implementation, includes compliance, monitoring, health effects, point of use, and exemptions and most likely with the exemptions, we'll be focusing more on the financial aspects of approving exemptions. So I hope you can join us then. Thank you.

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