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Quality of Water from Public-Supply Wells in the United States

<u>Slide 1: Title</u>

Thank you very much for taking the time to be here. It's a great honor for me to speak with you today.

Over the past 30 years, the U.S. Geological Survey, the Environmental Protection Agency, and others have produced numerous reports that include select water-quality findings for public wells. Most of these reports have focused on particular regions of the country or on specific types of contaminants.

The study I'll tell you about today complements these efforts. For the first time, we've synthesized water-quality findings for public wells for a wide range of contaminants at the national scale.

Our overall finding is that contaminants are widespread in untreated water from public wells, and that concentrations of potential concern are relatively common.

To explain what this broad finding means, I'll focus on three basic questions:

- First, how often are contaminants in public wells a potential concern for human health?
- Second, what are these contaminants and where do they occur?
- And third, what are the most important remaining information gaps?

Before answering these questions, let's start with some background on the importance of public wells to drinking water and on our assessment approach.

<u>Slide 2: Drinking-water sources pie chart</u>

In 2008, about 105 million people—more than one-third of the Nation's population—obtained their drinking water from public water systems that rely on groundwater supplies.

<u>Slide 3: Map of public-well users by county</u>

Public wells are the primary source of drinking water in large areas of the country, including many urban areas. All of the dark green areas on this map are counties where more than half of the population relies on drinking water from public wells, including much of the southwestern, southern, and central United States.

Slide 4: How this study is different

This study complements previous studies and the extensive monitoring of public water systems that’s required for regulatory compliance.

- First, more chemical contaminants were assessed in this study than in any previous national study of public wells.
- We focus on the quality of untreated source water. But, we also compared the quality of untreated source water and treated finished water in subset of samples.
- Nationally consistent methods for sampling and analysis, as well as low detection levels, enables comparisons of water-quality conditions among geographic areas and across the United States.
- Concentrations are compared to an expanded list of human-health benchmarks to evaluate contaminant occurrence in the context of human health.
- Lastly, we evaluate the co-occurrence of contaminants as mixtures because contaminants seldom occur alone.

Slide 5: Map of 932 public wells and principal aquifers

Our study is based on source-water samples from 932 public wells. The wells are shown as blue dots on this map, and each well was sampled once during 1993 to 2007.

Although clustered in some aquifer areas, the wells were randomly selected within these areas to represent typical aquifer conditions. We did not target areas of known contamination. The wells are located in parts of 41 states and in half of the principal aquifers used for public water supply.

Each colored area on this map represents a different principal aquifer rock type—each of which has different geologic characteristics. They’re called “principal aquifers” because of their size and importance for water supply.

Slide 6: 337 contaminants analyzed

Each source-water sample was analyzed for as many as 337 chemical contaminants, both inorganic and organic.

Most of the inorganic contaminants occur naturally, although the highest levels of nitrate usually originate from man-made sources such as fertilizers, livestock, and wastewater.

By contrast, the organic contaminants originate from man-made sources.

The Safe Drinking Water Act defines all chemicals detected in water as contaminants, but the presence of a contaminant in water does not necessarily mean that there’s a human-health concern.

Slide 7: Human-health benchmarks pie chart

To put our results in a context that makes sense for human health, we compared contaminant concentrations in source water to human-health benchmarks. These benchmarks are concentrations in drinking water below which adverse health effects are not expected.

Specifically, concentrations of contaminants that are regulated by the EPA in drinking water under the Safe Drinking Water Act were compared to Maximum Contaminant Levels, or MCLs. Unregulated contaminants were compared to Health-Based Screening Levels, or HBSLs. MCLs are legally enforceable drinking-water standards and HBSLs are not. HBSLs were developed by the USGS in collaboration with the EPA and others using EPA methods and their most recent peer-reviewed toxicity information.

Note that benchmarks are not available for 43 percent of the contaminants.

Eighty-three percent of the contaminants analyzed in this study are not regulated in drinking water. As you may hear later from Michael Shapiro, EPA uses USGS data on the occurrence of unregulated contaminants as part of their process for identifying contaminants that may require drinking-water regulation in the future.

Slide 8: Question #1

So, let's get on to the first question, "how often are contaminants a potential concern for human health?" To answer this, we looked at a combination of detection frequencies and concentrations relative to benchmarks.

Slide 9: Map of 22 percent of samples with concentrations greater than benchmarks

Contaminant concentrations were less than human-health benchmarks in most source-water samples. But, about 1 in 5 samples had one or more contaminants with concentrations greater than benchmarks. These wells are shown in red on the map.

Concentrations greater than benchmarks are potential human-health concerns, but don't mean that adverse effects are certain to occur because the benchmarks are conservatively protective, and most samples were collected prior to any treatment or blending of water.

An additional 58 percent of source-water samples had one or more contaminants with concentrations greater than one-tenth of benchmarks. This concentration level was used to provide an early and conservative indication of contaminants that may warrant additional monitoring, and may be important when considering contaminant mixtures.

All together, 80 percent of the sampled wells had concentrations greater than or approaching benchmarks. These wells were distributed throughout the United States and they withdraw water from all principal aquifer rock types.

Slide 10: Bar graph showing natural contaminants accounted for most concentrations greater than benchmarks—part 1

This graph shows the percentage of source-water samples with concentrations greater than benchmarks, broken down by type of contaminant, and whether the contaminant originates from natural or man-made sources.

Collectively, we found that naturally occurring trace elements and radionuclides accounted for most benchmark exceedances. For example, concentrations of one or more trace elements were greater than benchmarks in 16 percent of source-water samples.

By contrast, contaminants from man-made sources, including nitrate, pesticides, and volatile organic compounds accounted for fewer benchmark exceedances.

We'll see in a few minutes that these benchmark exceedances followed distinctly different patterns for natural and man-made contaminants depending on what type of aquifer they're in. Before showing you those findings, let's look at some of the differences between two types of aquifers.

Slide 11: Aquifer type

An aquifer is a geologic formation that can transmit substantial amounts of water to wells. This schematic shows a cross section of aquifers below the land surface.

Public wells withdraw water from either confined or unconfined aquifers. Confined aquifers are located beneath a relatively impermeable confining layer—such as clay or shale, and unconfined aquifers are aquifers in which the water table forms the upper boundary.

[Click to see animation about contaminant sources.] In general, unconfined aquifers are more vulnerable to man-made contamination from the land surface because they tend to be shallower and don't have a protective layer between the aquifer and the land surface. You'll see a specific example of this when Karen Burow and Nick Pinhey show you findings for public wells in Modesto, California.

[Click to see second part of animation.] Deeper wells in confined aquifers are generally less vulnerable to man-made contaminants, but are not totally protected. Public wells with large pumping rates can capture contamination from a large area and may draw in contaminated shallow groundwater by short-circuiting flow paths, such as abandoned wells or fractures.

Wellhead protection programs and related controls on contaminant sources are primary management tools used to reduce groundwater contamination from man-made sources.

Slide 12: Bar graph showing natural contaminants accounted for most concentrations greater than benchmarks—part 2

So now, let's look at the same summary of benchmark exceedances, but with results distinguished by confined and unconfined aquifers.

Trace elements and radionuclides were detected above benchmarks in samples from both confined and unconfined aquifers. This is expected because they originate primarily from aquifer materials, rather than from man-made sources at the land surface.

By contrast, almost all benchmark exceedances of nitrate, pesticides, and VOCs were in samples from unconfined aquifers. This is because these contaminants originate from human activities at the land surface.

Slide 13: Bar graph showing detection frequencies of man-made contaminants—part 1

It's also important that we look beyond simple benchmark exceedances and evaluate detections at all concentrations, as shown on this graph. When man-made contaminants are detected, it means that there are sources of contaminants and transport pathways that make groundwater vulnerable.

Recall that we just showed that there were relatively few benchmark exceedances for man-made contaminants. This finding is shown again as the red portion of the bars on this graph, and is the same information shown on the previous slide.

But, contaminants from man-made sources were frequently detected in public wells, including nitrate and a variety of organic contaminants. Nitrate occurs naturally, but concentrations above 1 milligram per liter usually indicate man-man sources. All together, one or more pesticides and volatile organic compounds were detected in nearly two-thirds of the samples.

Slide 14: Bar graph showing detection frequencies of man-made contaminants—part 2

Most of these man-made contaminants were detected more often in unconfined aquifers than in confined aquifers, consistent with their origin from sources at the land surface. But, surprisingly, these contaminants also were commonly detected in confined aquifers. This means that even some deep public wells in confined aquifers are vulnerable to contamination from man-made sources.

Slide 15: Compare concentrations of organic contaminants in source and finished water

We just saw that organic contaminants are frequently detected in source water. So, we examined whether they are also detected in finished drinking water by analyzing organic contaminants in a subset of paired source- and finished-water samples.

This graph shows results for the organic contaminants that were most frequently detected in source water, excluding disinfection by-products. Most of these are unregulated, or don't have benchmarks, but concentrations were less than available benchmarks in all finished-water samples.

Each symbol is the result for a single contaminant in a pair of source and finished samples. Symbols that fall on the diagonal line mean that concentrations in finished water are the same as in source water. Those along the bottom of the graph mean that contaminants were detected only in source water, possibly because they were removed or transformed during treatment.

The take-home message from these results is that when an organic contaminant was detected in both source and finished water, concentrations generally were similar. Because organic contaminants were frequently detected in source water, their frequent occurrence in finished water is likely.

But, it's important to note that disinfection was the primary treatment used at most of the sampled wells, and that disinfection generally is not designed to remove organic contaminants. But, additional treatment was used at some of the sampled wells.

Slide 16: Answers to Question #1

To sum up how often contaminants are a potential concern:

- More than 1 in 5 source-water samples contained at least 1 contaminant at concentrations greater than human-health benchmarks.
- Naturally occurring trace elements and radionuclides accounted for three-quarters of all benchmark exceedances, which occurred in samples from both unconfined and confined aquifers.
- By contrast, man-made contaminants accounted for one-quarter of benchmark exceedances—almost entirely in unconfined aquifers—because they originate at the land surface.
- The widespread occurrence of man-made contaminants indicates the ubiquitous nature of man-made contaminant sources.
- Lastly, organic contaminants in untreated source water also occurred in treated finished water at similar concentrations.

Slide 17: Question #2

Now, let's look which contaminants are of most concern in source water and where they occur.

Slide 18: 10 contaminants with concentrations greater than benchmarks

We found that 10 contaminants accounted for most concentrations greater than benchmarks in source water.

Half of these 10 contaminants are regulated, and therefore managed, in finished drinking water—they are shown in blue. Of those not regulated, MCLs have been proposed for radon, and manganese, boron, and dieldrin have gone through EPA’s regulatory determination process under the Safe Drinking Water Act, but were not selected for regulation. And strontium is on EPA’s most recent Contaminant Candidate List.

Seven of the 10 contaminants are from natural sources and include 3 radionuclides and 4 trace elements. Radon was compared to two different benchmarks, which is why the bar for radon has two different colors on this graph. Radon is unique in that the EPA has proposed a lower MCL and a higher Alternative MCL depending on whether programs are in place to reduce radon from all sources.

The three contaminants from man-made sources were dieldrin (an insecticide that is no longer used), nitrate (a nutrient), and perchloroethene (or PCE, a solvent).

We’ll now look more closely at the geographic distribution of radon, arsenic, and man-made organic contaminants.

Slide 19: Map of radon

Radon is a naturally occurring carcinogen. It’s a soluble gas that originates from the radioactive decay of uranium. Only 3 source-water samples had radon concentrations greater than its higher proposed Alternative MCL, shown in red on the map. But, more than half of the samples had radon concentrations greater than its lower proposed MCL. Concentrations greater than this lower proposed MCL occurred in every principal aquifer rock type, but most frequently in the western and northeastern United States.

Slide 20: Map of arsenic

Arsenic is a naturally occurring trace element that’s a common trace constituent of many rock-forming minerals. It’s also a carcinogen. Arsenic concentrations were greater than its MCL in 10 percent of source-water samples. These samples are shown in red on the map, and although they were distributed across the United States, about three-quarters of them were from public wells in the western half of the United States. This finding is consistent with findings from previous national-scale arsenic studies. Arsenic concentrations were greater than one-tenth of its MCL in an additional one-third of samples.

Slide 21: Map of pesticide compounds and VOCs

As you saw earlier, pesticides and VOCs were frequently detected in source-water samples. Concentrations were greater than benchmarks in about 5 percent of these samples, shown in red on the map. About two-thirds of these samples were from public wells in the highly populated areas of states bordering the East Coast. An additional 5 percent of samples contained one or more pesticides or VOCs at concentrations approaching benchmarks.

Slide 22: Answers to Question #2

To summarize our question about which contaminants are of most concern and where, we found that:

- Seven of the 10 contaminants that accounted for most benchmark exceedances are naturally occurring radionuclides and trace elements.
- Radon was the radionuclide most frequently detected above its proposed MCL, mostly in western and northeastern states.
- Arsenic was the trace element most frequently detected above its MCL, typically in western states.
- And, pesticides and VOCs were detected above benchmarks in about 5 percent of samples, primarily in East-Coast states. Dieldrin and PCE accounted for most of these cases.

Slide 23: Question #3

We've learned a lot in this study, but also identified some important information gaps about contaminants found in public wells.

Slide 24: Frequently detected contaminants without benchmarks

The first information gap is the incomplete availability of human-health benchmarks. Without benchmarks, it's impractical to assess the potential significance of contaminant occurrence to human health.

Benchmarks were not available for some commonly detected contaminants because of insufficient toxicity data. These contaminants included several herbicide degradates (shown in green bars), MTBE (a gasoline oxygenate), and 1,1-dichloroethane, which is a solvent.

MTBE and several of these herbicide degradates are on EPA's most recent Contaminant Candidate List.

Slide 25: Map of mixtures

A second gap is the lack of information about the potential health significance of contaminant mixtures. Benchmarks generally aren't available for combinations of two or more contaminants.

We examined mixtures in a subset of source-water samples in which most contaminants were analyzed. We found that contaminants usually co-occurred with other contaminants as mixtures. Mixtures of contaminants with concentrations approaching benchmarks were found in 80 percent of samples, but mixtures of contaminants above benchmarks were found less frequently, in 4 percent of the samples.

Samples with mixtures were distributed throughout the country with no clear geographic pattern.

Slide 26: Bar graph showing complexity of mixtures

A large number of the mixtures were comprised of 2, 3, 4, or even more contaminants. More than half of the samples contained 3 or more contaminants, each with concentrations greater than one-tenth of individual benchmarks. The most complex mixtures in source water—those with the greatest number of contaminants—were most often detected in unconfined aquifers.

The most common simple mixture was nitrate and radon, which was detected in nearly one-third of the samples.

Slide 27: Answers to Question #3

To summarize our third question, there are three particularly important information gaps:

- First, more information is needed on the potential health effects of individual contaminants that don't have benchmarks because of insufficient toxicity data.
- Research also is needed on the potential health effects of contaminant mixtures. The widespread and frequent detections of mixtures in source water is a matter of increasing attention because the total combined toxicity of contaminants in water may be greater than that of any individual contaminant.
- Third, there are thousands of contaminants beyond the 337 analyzed in this study that may be present in source water, including industrial and pharmaceutical chemicals. We need to continue to develop new analytical methods to be able to assess the occurrence of these contaminants.

Slide 28: Summary of key findings and implications

I'll close by re-emphasizing a few of our key findings and their implications. [Animated in slide show; each bullet appears with a separate click.]

- First, more than 1 in 5 source-water samples had one or more contaminants at concentrations greater than benchmarks. For these wells, either treatment or blending with higher-quality water sources is used by water utilities to decrease concentrations of regulated contaminants below MCLs. Water utilities, however, are not required to treat water for unregulated contaminants, which accounted for about 40 percent of the benchmark exceedances.
- [Click] Second, concentrations of naturally occurring contaminants exceeded benchmarks three times more often than for man-made contaminants. These high concentrations were detected in both confined and unconfined aquifers. Traditional wellhead protection approaches generally are not designed to control natural contaminants unless they are being mobilized by human activities.
- [Click] Third, the frequent detections of man-made contaminants in source water indicate the vulnerability of water-supply aquifers to contamination from human activities. Almost all benchmark exceedances for man-made contaminants were in unconfined aquifers. In contrast to natural contaminants, this means that wellhead protection programs and related strategies are important for preventing or reducing contamination from man-made sources.
- [Click] Lastly, we are working to narrow some information gaps. To help human-health researchers to target and prioritize their toxicity assessments, USGS shares its water-quality findings with EPA and others on frequently detected individual contaminants and mixtures that don't have benchmarks. At the same time, USGS is evaluating which new contaminants are expected to occur in source water, and is developing new analytical methods to measure them. USGS will begin using these new methods in FY 2013.

Slide 29: More information

Thank you very much for your time and attention.