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Quality of Water from Private Wells in the United States

1) **Slide 1 – Title**

Today I'm going to talk about our national findings on the quality of water from private domestic wells, one of the primary sources of drinking water in the United States. Studies over the past 30 years have shown that contaminants such as bacteria, nitrate, and pesticides can occur in water from private wells. These past studies, though, have generally focused on a limited number of contaminants or on areas of known concern. The new study that I'll be talking about greatly expands the number of contaminants assessed and, through its broad geographic coverage, allows us to begin to understand the quality of water from the major aquifers used for domestic supply in the United States.

2) **Slide 2 Drinking-water sources pie**

Private wells, which typically serve single households, supply 15% of the U.S. population—or about 43 million people with drinking water.

Although a key component of our National water supply, private wells are not regulated under the Federal Safe Drinking Water Act, which applies only to public-water supplies. And in most cases, the quality of water from private wells also is not regulated by State laws or local laws after the well is installed. It's up to the homeowner to monitor the quality of their well water and take action if they need to.

3) **Slide 3 Map of private-well users by county**

Private wells are the primary source of drinking water in many rural areas.. All of the dark blue areas on this map are counties where more than half the population rely on private wells, and there are extensive other areas, shown in light blue, where more than a fourth of the population rely on these wells. In areas such as these, concerns about possible contaminants are greatest because of the number of people who may be affected.

The lack of regular monitoring of private wells makes periodic large-scale assessments of their water quality, such as the one I'm talking about today, particularly important. Studies like this, as well as similar studies at state and county levels, are often the only sources of information about the quality of this important drinking water resource.

4) **Slide 4 Map of 2,100 study wells and principal aquifers**

Our study is based on samples from more than 2,100 private wells across the country. The wells are located in 48 states and within 30 regionally extensive aquifers—aquifers being simply units of rocks or sediments that are porous and saturated, so that they can yield water to wells. The aquifers that we sampled are shown on the map, with colors that indicate different aquifer rock types. They're called "principal aquifers" because of their extent and their importance for water supply.

As you can see, the sampled wells are not evenly distributed across the country. That's because they are located within study areas of the National Water Quality Assessment Program, study areas that were chosen because of their overall importance to the water resources of the Nation. Within the ground-water study areas, the wells were randomly selected, and they were sampled and analyzed using consistent methods, so that data from across the country are comparable and can be synthesized to yield a National perspective. Wells were sampled before any water treatment systems in the home.

Each well was sampled once during 1991 to 2004 as part of these NAWQA ground-water studies, which were staged over time as part of these broad resources assessments. Because of the slow rate of flow and chemical change typical of ground water, the results can be synthesized to provide a composite snapshot of the study period.

Overall, we measured as many as 219 different properties and contaminants in the 2,100 wells that we sampled, including trace elements, nitrate, radon, and man-made organic compounds like pesticides. We evaluated the distribution of contaminants both individually and as they occurred together as mixtures. For the evaluation of mixtures, we focused on a subset of about 1,400 wells that had the most complete chemical analysis—these wells are shown in yellow on the map.

5) **Slide 5 Human-health benchmarks pie**

To put our study results in a context that makes sense for human health, we compared measured contaminant concentrations to human-health benchmarks. Human-health benchmarks are concentrations in drinking water below which or at which adverse health effects are not expected. So, concentrations greater than these benchmarks indicate a potential concern for human health. Contaminants regulated under the Safe Drinking Water Act were compared to EPA Maximum Contaminant Levels, or MCLs, and unregulated contaminants were compared to USGS Health-Based Screening Levels, or HBSLs. MCLs legally apply only to public-water supplies, but they're commonly used to evaluate the quality of water from any drinking-water source. HBSLs are nonenforceable guidelines developed by USGS in collaboration with EPA, using EPA methods and the most recent toxicity information. In many cases, HBSLs are the same as published EPA health guidelines, (like lifetime health advisories) for these unregulated contaminants. We used MCLs for all contaminants that had them, about one-quarter of those that we measured, and we used HBSLs for about half. About a quarter of the contaminants weren't evaluated in a human health context because they don't have health benchmarks.

6) **<u>Slide 6</u> Questions**

With this background in mind, let's get to the results. I'm going to summarize our major findings by answering three basic questions:

How often are contaminants a potential concern for human-health in private wells?
What are these contaminants and where do they occur?
Do these contaminants occur alone or together with others as mixtures?

7) **<u>Slide 7</u> Map of 23 percent of wells with at least 1 contaminant > benchmark**

The answer to the first question—how often is there a health concern?—is that, while contaminants were less than benchmarks in most wells, we found that 23 percent of wells had at least 1 contaminant greater than a human-health benchmark. In other words, more than one in five of the sampled wells had one or more contaminants at levels of potential health concern, if not treated prior to use. Note that bacteria are not included here, because we did not sample them in enough wells.

These wells, which are shown in red on the map, were widely distributed across the country, but many are clustered in particular geographic regions.

In order to better understand this distribution of potential water-quality concerns, we need to address the second question—Which contaminants are responsible and where?

8) **<u>Slide 8</u>. Bar graph of most frequently occurring contaminants > benchmarks**

The contaminants that most often exceeded health benchmarks were primarily from natural geologic sources. They included radon, strontium, arsenic, manganese, uranium, boron, and fluoride. Along with nitrate, which is mostly from man-made sources, each of these contaminants was present at concentrations greater than their human-health benchmarks in more than 1 percent of the wells.

Note that radon is compared to 2 values, both proposed MCLs. EPA has proposed an MCL of 300 pCi/L, along with a higher alternative MCL of 4,000 pCi/L for places with programs to reduce radon in the home from all sources.

We'll look now more closely at radon, arsenic, and nitrate, as we continue to address the question of which contaminants are of most concern, and where, and we'll consider some of the factors that determine concentrations—geology, water chemistry, and land use.

9) **Slide 9 Radon map**

Radon is a naturally occurring, soluble gas that originates from the radioactive decay of uranium; it's a carcinogen. In drinking water, it poses a problem when people inhale it after it comes out of solution, for example in the shower.

In the private wells that we sampled, radon concentrations were greater than the lower proposed MCL in 65 percent of the wells—these are shown in blue—and greater than the higher proposed MCL in 4.4 percent of wells—those shown in red. You'll notice that these red wells are clustered in the northeast, in the central and southern Appalachians, and in an area of Colorado. The crystalline-rock aquifers that occur in these areas are relatively enriched in uranium-bearing minerals, and the concentrations of radon in well water reflect the distribution of these uranium-bearing rocks.

10) Slide 10 Radon map – eastern crystalline aquifers only

In areas where the crystalline-rock aquifers are used for domestic water supply, the percentage of wells with radon levels of concern can be much greater than the national percentages—nearly 30% of sampled wells in these aquifers in the eastern U.S. exceeded the higher proposed MCL of 4,000.

11) **Slide 11 Arsenic map**

Arsenic is a naturally occurring trace element and is a common trace constituent of many rock-forming minerals. It's toxic at elevated levels and also is considered a carcinogen.

More than 90 percent of the wells that we sampled had concentrations of arsenic less than its MCL of 10 parts per billion, shown in tan or white. However**,** 6.8 percent of the wells, shown in red, had arsenic concentrations greater than the MCL. As you can see, concentrations greater than the MCL occurred in the Northeast, upper Midwest, and western United States, which is consistent with previous studies of arsenic in ground water, and these wells tap water from several different aquifers. Although arsenic occurs in many different rock types, its presence in ground water depends on both the water chemistry and the mineral form of the arsenic in the rocks—for example, the combination of high dissolved oxygen in ground water and arsenic in sulfide minerals is one combination that can result in high arsenic concentrations in ground water.

12) **Slide 12 Arsenic map – southern High Plains aquifer only**

Like radon, arsenic concentrations can be more of a concern in some aquifer areas than nationally—for example, in the southern High Plains aquifers, about 30 percent of the sampled wells had concentrations greater than the MCL.

13) **Slide 13 Nitrate map**

Nitrate is a little different from radon and arsenic because, although it does occur naturally in ground water, high concentrations—typically those above 1 part per million-- are usually caused by man-made sources, such as fertilizers, manure, and septic systems.

About 95 percent of the wells that we sampled had concentrations of nitrate less than its MCL of 10 parts per million. However, we found nitrate concentrations greater than the MCL in 4.4 percent of the sampled wells. These high concentrations in the private wells were found in all parts of the country except the Southeast, where environmental conditions may favor the natural transformation of nitrate to nitrogen gas, as seen in previous studies.

And also unlike radon and arsenic and consistent with its man-made sources, land use rather than geology is important for nitrate.

14) **Slide 14 Bars of nitrate concentrations by land use**

High concentrations of nitrate were found most often in agricultural areas. 7 percent of private wells in the national data set that were surrounded mostly by agricultural land had nitrate concentrations greater than the MCL of 10 parts per million. This compares to about 3 to 4 percent of wells surrounded by urban or mixed land use and less than 1 percent of wells in mostly undeveloped areas.

The finding of high nitrate concentrations in agricultural areas is similar to other studies. In fact, separate NAWQA studies of ground water in areas of intensive agricultural land use found that more than 20 percent of the private wells sampled in those areas had nitrate concentrations greater than the MCL of 10 parts per million. Again, this serves to emphasize an important point to remember for all contaminants—that benchmark exceedences and health concerns can be much higher is some geographic areas than the national statistics indicate.

15) **Slide 15** **Pesticides and VOCs map**

Now I'm going to talk about some contaminants that very seldom exceeded benchmarks. We sampled for about 170 different pesticides and VOCs, or volatile organic compounds, or such as industrial solvents and gasoline chemicals, and found that less than 1 percent of wells had any of these contaminants greater than a health benchmark.

Although they rarely exceeded benchmarks, as shown by few red dots on the map, lower-level detections of pesticides and VOCs were common and occurred in about 60 percent of wells. The most frequently detected organic compounds at these low levels reflected a wide variety of sources and uses, and included the pesticide atrazine; the gasoline additive MTBE, chloroform, and several industrial solvents and refrigerants. These compounds were measured at very low levels—often 100 to 1000 times below the health-benchmark values, and this was done to provide a sensitive measure of their presence or absence. Detections of pesticides and VOCs, even at low levels, are important to recognize and understand because they demonstrate that man-made contaminant sources and transport pathways are affecting our sources of drinking water.

16) **Slide 16** **Bars for microbial contaminants**

There are 2 more types of contaminants that I'd like to touch on today, starting with bacteria. We sampled for total coliform and *E. coli* bacteria in about 400 wells. These bacteria typically are not harmful themselves, but they are commonly used as indicators of the possible presence of fecal contamination and pathogens because they live in animal intestines. Total coliform bacteria can live in soil as well as in animals, whereas *E. coli* typically only comes from animals. We found *E. coli* bacteria in 8 percent of the wells that we sampled, and total coliform bacteria in 34 percent of the wells. We sampled too few wells to evaluate any geographic patterns, but bacteria tended to be detected more frequently in porous and fractured-rock aquifer types, which allow rapid infiltration of water.

17) **<u>Slide 17</u> Bars for secondary contaminants**

The last group of contaminants are not health concerns, but affect the aesthetic quality of water and are certainly important to homeowners. These secondary contaminants can result in unpleasant color or taste, or staining of laundry, sinks, or other effects. EPA has nonenforceable recommendations for these in public-water systems. We found that about half the private wells had concentrations or values outside of the recommended ranges. Individually, pH, total dissolved solids, iron, and manganese, were outside recommended values in 15 to 21 percent of the wells we sampled, with geographic patterns apparent for some of these. Fluoride concentrations were greater than the recommended value of 2 mg/L in 4 percent of the sampled wells; fluoride concentrations at these levels are a concern because they can lead to staining of teeth in children.

18) **<u>Slide 18</u> Bars for contaminant mixtures**.

This brings us to the third and last question—are contaminants occurring alone or as mixtures of multiple contaminants?

In answering our first question about the frequency of human-health concerns, we reported that 23 percent of the private wells that we sampled had one or more contaminants greater than a health benchmark.

When we look more closely, we found that 4 percent of wells sampled had 2 or more contaminants (mixtures of 2 contaminants) greater than benchmarks.

Now, at this time, there are few health benchmarks specifically for mixtures of contaminants such as these. But we know that contaminants, when they occur together, may have different health effects than when they occur alone, and health effects may be additive. For example, the combination of nitrate and the triazine pesticides such as atrazine may be a health concern—because nitrate and such pesticides can react in the body to form compounds that look like carcinogens—but there presently are no health benchmark values for nitrate and these pesticides when they occur in that mixture. The health effects of mixtures is an area of active research and there remains a lot of uncertainty. As a screening level assessment, then, in this study, we used the criterion of one-tenth of a health benchmark to identify contaminant concentrations that were approaching health benchmarks, and so might be of health concern when the contaminants occur in mixtures. This criterion, of one-tenth of a benchmark has been used as a screening level a number of Federal and state and agencies for preliminary risk and vulnerability assessment. At these screening levels, we found mixtures of 2 or more contaminants in 73% of wells, and 30% of wells had 4 or more contaminants at these levels. The most common components of these mixtures were the contaminants we've been talking most about, including—nitrate, arsenic, and radon.

19) **Slide 19 Mixtures map**

Mixtures of contaminants greater than health benchmarks, shown in orange, were found mostly in the western U.S. and northeast, whereas mixtures of contaminants exceeding one-tenth of their benchmarks, in blue, were widespread among the areas sampled.

Again, it's important to point out that health effects have not been investigated for most of the low-level mixtures that we found, and, there may not be any health effects. The characterization and understanding of contaminant mixtures is really in its infancy; and it's a long-term research topic that will be talked about for a long time to come. However, the specific combinations that we document in this study can provide a useful information for prioritizing some of this mixtures research.

Now I'm going to wrap up my part of today's briefing by reminding you of key answers to our three questions—How often is there a human-health concern? What contaminants are causing it and where? Are contaminants occurring as mixtures?—and then extending our answers to some basic implications for water-quality management.

20) **Slide 20** ***Final 1*****: 23% Map**.

First, recall that more than 1 in 5 of the private wells that we sampled across the country had 1 or more contaminant greater than a human-health benchmark, and that these wells are not routinely monitored by public agencies.

While this finding indicates that the majority of private wells don't have health concerns, it also points to the critical importance of public education and water-quality testing, to identify those private wells that do have health concerns. Homeowners need to understand the potential for contaminants in their well water and the value of testing. This is particularly important because the contaminants of most frequent concern are naturally occurring, and may be present in areas where the ground water doesn't seem vulnerable to contamination—for example, in an area that has historically been undeveloped. These contaminants aren't protected against with traditional approaches to manage contaminant sources near the well.

Also, because ground water moves slowly, contaminants such as nitrate from man-made sources may be present in ground water from previous activities. For example, when farmland is converted to suburbs, new private wells may pump water with high nitrate concentrations left behind from the farming activities.

21) **Slide 21** ***Final 2*****: Radon, Arsenic, and Nitrate Maps**

In answering our question about which contaminants are of most frequent concern, we saw that, again, most are naturally occurring elements or nitrate, and some show distinct geographic patterns, due to geology, water chemistry, and land use. This means that the potential for adverse health effects from contaminants in private wells varies across the country and is higher in some areas than in others. The best way to address this type of water quality concerns may be to target attention in specific areas where (1) high concentrations of some contaminants are more common and (2) a large part of the population depends on private wells. This is already being done in some areas where public agencies recommend different types of testing that are targeted at the contaminants in their service areas.

In developing these kinds of approaches to monitoring that target such areas, however, we do need to remember that, ground water concentrations can be extremely variable, locally and with depth in the aquifer—and this again points to the importance of testing of individual wells in any locality.

22) **Slide 22** ***Final 3*****: Mixtures Map**

Lastly, we found that mixtures of multiple contaminants above health benchmarks are relatively uncommon in private wells, but that lower level mixtures of contaminants, that are greater than one-tenth of benchmarks, are common and widespread. These findings reinforce the growing understanding that contaminants usually occur in our sources of drinking water as mixtures of multiple contaminants, rather than by themselves, Much more information is needed about the possible health effects of these mixtures, and this is a key area of need for future research.

23) **Slide 23** ***Final 4*****: Photos and web site for report**

Overall, this National assessment of private wells indicates that greater attention to the quality of drinking water from private wells, which are depended on by more than 40 million people, is an important step toward the goal of protecting public health.