PURDEX IN FOCUS:
ARSENIC IN THE NATION'S TAP WATER

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The *Purdex In Focus* series highlights a particular contaminant found in tap water and presents a more detailed analysis of its occurrence, and potential health risks from exposure to the contaminant, in drinking water. The data used in all of the analyses are the same data the EPA and state primacy agencies use to determine compliance with federal drinking water standards.

Summary

Arsenic is ubiquitous in our environment and consequently we are all exposed to it in our air, water and food. Organic forms of arsenic are used in agricultural operations while inorganic arsenic is primarily used in nonresidential and industrial applications. Arsenic will generally settle into soil and sediment where it can migrate into ground and surface waters. Much of human exposure to inorganic arsenic comes from drinking water drawn primarily from ground water sources. Higher levels of arsenic in ground water have been linked to human activity but drought conditions can also significantly increase arsenic concentrations in ground water. Over 98 percent of the public water systems in the United States that report arsenic in their tap water use water from a ground water source, and most of these are small water systems serving populations of less than 3,000 people. Eighty percent of the water systems in this study reported average arsenic drinking water concentrations of less than two parts per billion (ppb), while four percent of the systems exceeded the U.S. Environmental Protection Agency's maximum allowed level of 10 ppb. In most states where higher arsenic concentrations are being reported, the number of arsenic health-based standard violations seems to be decreasing yearly since 2008. Although the acute health risks for the more than 3 million people who are consuming moderate to high amounts of arsenic in their drinking water are well defined in the medical literature, what is often overlooked are the potential health risks affecting the 49 million people exposed to long term, low doses of arsenic, a known carcinogen. Home filtration systems can remove arsenic from drinking water and are a feasible and cost effective alternative when considering the health benefits.

Introduction

Elemental arsenic is naturally occurring and widely distributed in the Earth's crust. It is toxic for both animals and plants, in spite of evidence that it is also an essential dietary element. It is tasteless, colorless and odorless. We are all exposed to small amounts of arsenic in the air we breathe, the water we drink and the food we eat. It may be present in drinking water as a result of the weathering of arsenic-containing minerals by natural processes or related to mining and smelting; as runoff from arsenic-containing pesticides used in orchards; in wastewater runoff from glass and electronics production; from coal-fired power plants or underground coal fires; or from volcanic eruptions. It is usually found in the environment combined with other elements like oxygen, chlorine, iron and sulfur forming inorganic arsenic compounds. Arsenic combined with carbon and hydrogen is referred to as organic arsenic.

All of the arsenic used in the United States in 2012 was imported, mostly from Morocco and China.[1] During 2012, 6,180 metric tons of arsenic was imported, which is a 26 percent increase from 4,910 metric tons in 2011.[2] About 90 percent of arsenic produced (in its inorganic form) is used as a wood preservative in nonresidential applications like utility poles, guardrails, pilings and railroad ties. Inorganic arsenic was used predominantly as a pesticide on cotton fields and orchards until it was banned for agricultural use in the early 1990s. However, organic forms of arsenic are still used as pesticides, principally on cotton, and used as an additive in animal feed. Organic forms of arsenic are mainly found in fish and shellfish and are considered less toxic to humans than the inorganic form. It was hoped that with the ban on inorganic arsenic in pesticides we would see less and less of it in our environment; however, the continued use of arsenic in the production of cellular phones, light-emitting diodes in general and automotive lighting applications are expected to increase arsenic use in the years ahead.

Recent reports from the U.S. Food and Drug Administration (FDA) have shown arsenic to be found in our food supply like pear and apple juices and concentrates, and in rice and rice products.[3] However, much of human exposure to inorganic arsenic comes from drinking water.[4] Inhalation (i.e., from boiling water on the stove) and skin contact (i.e., showering and bathing) are not considered exposure routes of concern for arsenic in tap water. Both inorganic and organic arsenic forms will be expelled from the body in urine. Most of the inorganic form will be gone within several days, although some will remain for several months or even longer. Most organic forms will be expelled in a matter of days.

The Department of Health and Human Services, International Agency for Research on Cancer and U.S. Environmental Protection Agency (EPA) have all determined that inorganic arsenic is a known carcinogen. (Almost no information is available on the effects of organic arsenic compounds in humans.) Long-term exposure to inorganic arsenic has been linked to cancer of the liver, bladder, kidney, lungs, and prostate. Noncancerous effects from exposure include blindness, diarrhea, discoloration and thickening of the skin, nausea, stomach pain, and vomiting.[5] Because arsenic exposure in humans can cause short- and long-term adverse health effects the EPA has set the maximum contaminant level (MCL) for arsenic in drinking water at 10 parts per billion (ppb). The FDA also set the same standard for arsenic in bottled water. (Click here for a discussion on how MCLs are established.)

Inorganic arsenic exists in drinking water primarily in two forms, as arsenite (AsIII) and the less toxic form arsenate (AsV). These two may or may not exist in equal proportions in the water; it all depends on water conditions and chemistry (pH, amount of available oxygen in the water, etc.). The importance of distinguishing between these two forms will be discussed in a later section of this report.

Data Source and Analysis

All of the water sample data used in this report comes from the Purdex database, which represents a collection of millions of drinking water sample test data from public water systems throughout the nation. (State primacy agencies and EPA use the same data to determine compliance with drinking water standards.) Arithmetic means of treated drinking water sample data, and data from untreated ground water sources meant for human consumption, were used in this analysis as calculated averages better represent estimated contaminant concentrations in a typical drinking water distribution system. Raw water data from pretreated water sources not meant for human consumption were not used in this analysis. Only data collected from 2012 were included unless otherwise noted. Individual water system personnel managed sample collection activity and only state-certified laboratories were employed to analyze the samples using the same analytical methods for every sample as required by EPA. For purposes of this report, it is assumed that all related sample collection, handling, and analytical activity, as well as primacy agency reporting and record keeping, met all federal and state regulatory requirements and best-practices protocols. However, with the very large number of, and varied procedures for, manually recording sample analysis results, and since Purdex did not have oversight of any step in the process, it is expected that human error might have an (insignificant) impact on reported results.

Some states are not part of this analysis because we were not able to obtain the necessary data from them, or no water system in the state sampled for arsenic in 2012. These include Arkansas, Alabama, Colorado, Kansas, Michigan, Mississippi, New Hampshire, North Dakota, West Virginia, South Dakota, Oklahoma, and Utah. Arsenic sampling was performed by water systems in some of these states in prior years but since this report covers only sample activity in 2012, those sample results were not included in our analysis. Based on their previous years' data, it is expected that the general conclusions regarding regional trends drawn from our analysis can be equally applied to these states as well.

Arsenic in Our Environment

EPA's National Priorities List, which lists the most serious hazardous waste sites in the nation, has identified arsenic in 1,149 of the 1,648 current or former NPL sites.[6] Also, about 30 percent of the 1,191 Superfund sites categorize arsenic as a "contaminant of concern".[7] Apparently, high arsenic in ground water associated with industrial waste disposal is common. Most public water systems that report arsenic in drinking water use water from a ground water source. Even though ground water is far more likely to contain high levels of arsenic than surface water, it would be incorrect to assume that a large portion of ground water in the U.S. contains high arsenic. On average, ground water in the U.S. typically contains low to very low arsenic concentrations.[8] Based on our findings, about 80 percent of water systems in 2012 reported less than 2 ppb of arsenic in their tap water while 4 percent of the water systems exceeded the maximum allowed level of 10 ppb.

The parts of our country where agriculture is the primary economic driver generally shows higher arsenic compounds in the soil and water. Moderate to high arsenic concentrations appear to increase from east to west across the U.S. North central and western regions of the country have the highest arsenic levels in surface water and ground water, respectively. Agricultural soils where arsenic-containing compounds were used as pesticides have shown to still contain higher levels of arsenic even decades after it was banned for use as a pesticide. This is potentially a significant issue because there is evidence that in some cases arsenic will migrate into shallow ground water from the topsoil.[9] Further, when phosphate fertilizers – often used in agricultural processes – are applied to soil containing arsenic the potential for arsenic migration into ground water significantly increases.[10]

Atmospheric precipitation, surface water, and the soil and rock formations surrounding ground water aquifers, are all potential sources of arsenic in ground water. Arsenic cannot be destroyed in the environment; it can only change form, or become attached to or separated from other particles. Arsenic released from power plants and other combustion processes usually attach to particles in the air where they can be carried long distances by the wind before settling again on the ground via precipitation. Though it should be noted that precipitation, in absence of human activities (like smelting operations), contributes very little to arsenic concentrations in drinking water.

Arsenic entering a waterway will either stick to particles in the water or in the sediment on the bottom of lakes or rivers, and some will be carried along in the water. Ultimately, most arsenic ends up in the soil or sediment. (Although some fish and shellfish take up arsenic, which may build up in tissue, most is in the less-harmful organic form.) The influence of high pH, total dissolved solids (TDS), and iron content in water tends to contribute to high arsenic concentrations.[11,12] For example, iron and sulfur in the water can easily combine with arsenic trapped in the sediment or geologic formations encasing the ground water aquifer, to form arsenic-containing molecules. These molecules can then be dissolved in the water, releasing free elemental arsenic in the process. Arsenic released from these types of molecules (iron oxides, specifically) appears to be the most common cause of regionally high arsenic concentrations in drinking water.[11]

Drought conditions can also have a significant impact on the levels of arsenic in water. Through a process known as evaporative concentration, as the water level decreases the amount, or concentration, of arsenic present in the water increases. To illustrate this imagine adding a single drop of blue food dye to a 5-gallon container and an 8-ounce cup both filled with water: relative to the amount of water in each container, the smaller container has a visibly higher concentration of blue dye even though both containers had the same amount of blue dye added. Since arsenic will not evaporate, surface water and ground water can have high arsenic concentrations under drought conditions. In fact, research has shown that evaporative concentration of ground water is a contributing factor leading to high arsenic concentrations in drought stricken areas.[12]

Arsenic in Tap Water

There are 49 million Americans drinking, cooking with, and bathing in at least some detectable amount of arsenic in their tap water. The top ten states whose water systems reported the least amount of arsenic in their drinking water in 2012 are (in order of state-wide calculated averages) South Carolina, Tennessee, North Carolina, Kentucky, Hawaii, Georgia, Missouri, Rhode Island, Virginia and Connecticut. The top ten states reporting the highest levels of arsenic are shown in Table 1. It should be noted that water systems in Nebraska and Utah have historically reported arsenic levels that would have placed them on the list but because they did not report any sample data from 2012, we did not include them in this report.

Table 1. Top 10 States Reporting the Highest Tap Water Arsenic Levels in 2012

			Public Water Systems Reporting Moderate-High Yearly Averages[1]		Public Water Systems Reporting High Yearly Averages Above MCL[2]	
State	**State-wide Arsenic Average (ppb)**	**No. of Public Water Systems**	**Percent of Systems**	**Total Population Served**	**Percent of Systems**	**Total Population Served**
Idaho	7.46	27	48	2,000	18	1,000
California	6.51	1,172	26	800,000	16	200,000
Nevada	6.23	187	29	60,000	13	12,000
Texas	6.07	1,313	16	>1 million	7	200,000
Alaska	5.92	97	12	2,000	10	9,500
New Mexico	5.81	292	15	91,000	6	43,000
Louisiana	5.77	92	18	23,000	6	4,300
Washington	5.51	432	22	61,000	10	15,000
Arizona	5.26	316	34	>1 million	7	9,000
New York	5.12	727	3	5,300	2	1,300
			Total	> 3 million		495,100

[1]Greater than 6 ppb
[2]Greater than 10 ppb

Over 3 million people could potentially be consuming moderate to high amounts of arsenic in their drinking water (> 6 ppb). Further, about a half million people are using tap water from water systems reporting arsenic levels exceeding the health standard of 10 ppb. Texas, Arizona and California collectively show the highest proportion of people impacted. The states with the highest reported levels of arsenic are from parts of the country where agricultural operations are wide spread or where historically high drought conditions exist. However, whether the higher arsenic levels in these areas are specifically the result of agricultural or industrial processes, or from the evaporative concentration effect caused by drought conditions, is unclear. More research is needed before a definitive answer can be given. (The United States Geological Survey has published research on this subject and the reader is encouraged to review their findings on their website.)

Ninety-eight percent of the public water systems reporting higher levels of arsenic use ground water as their primary drinking water source. Most of these systems (92 percent) serve a population of less than 3,000 people, which places them in the category of small or very small public water systems. This is significant because unlike larger water systems with better access to funding sources, these smaller systems might not have the available capital or resources to invest in treatment technologies required to reduce arsenic concentrations in their drinking water. The EPA and state officials will allow small water systems under certain conditions to exceed the drinking water standard for a period of time, in order to give them extra time to raise the necessary capital required for installation of water treatment equipment to reach and maintain the standard. Whether this is the reason for the high percentage of small systems reporting higher levels of arsenic in their water is beyond the scope of this report but certainly worth investigating further.

It is noteworthy to highlight the fact that one in six Americans, who are consuming lower levels of arsenic in their tap water, may be at an increased risk of getting cancer. While not causing any immediate adverse health effects at these lower levels, exposure to low doses of arsenic in drinking water, over an extended period of time, has been shown to cause cancer. Therefore, any detectable level of arsenic in tap water should be considered a potential health risk.

It is difficult to determine if the higher levels of arsenic reported by water systems are consistent from year to year because not all water systems are required to sample for arsenic in their drinking water every year. (Click here for a discussion on why public water systems do not sample for contaminants every year.) Given that this type of trend analysis would require consistency in sample collection protocols to accommodate for differing water characteristics, seasonal and temporal variability, and since the presence of arsenic might be location-specific, any conclusions would be anecdotal at best. From the historical record, though, it does appear that the water systems reporting higher levels of arsenic in their drinking water have consistently reported similar levels year over year since 2008.

Public water systems are in violation if arsenic levels in the drinking water exceed the health-based standard of 10 ppb. As shown in Table 2, Texas and California had the highest total number of arsenic MCL violations at 1,987 and 1,414 respectively, in the period 2008-12. In Arizona, as a proportion of all health-based violations, 60 percent were for arsenic alone. With the exception of Washington and Alaska, it appears that the majority of the states in Table 2 are trending towards issuing fewer arsenic violations, which might be an indication that more and more water systems are complying with the drinking water standard by possibly installing better water treatment technologies. The reader is cautioned, though: due to known issues of underreporting violation information by state drinking water offices,[13] this conclusion should be weighed accordingly.

Table 2. Arsenic Maximum Contaminant Level (MCL) Violations For 2008-2012

	Arsenic MCL Violations		No. Of Arsenic MCL Violations By Year				
State	Total No. of MCL Violations Issued by State	Percent of Arsenic MCL Violations	2008	2009	2010	2011	2012
Texas	1987	28	307	350	439	460	431
California	1414	41	279	305	294	288	248
Arizona	745	60	166	226	188	94	71
Idaho	431	40	174	118	111	66	27
New Mexico	390	32	64	99	87	78	62
Nevada	289	49	19	88	73	68	41
New York	184	15	40	51	48	29	16
Washington	138	40	-	-	57	28	53
Alaska	89	13	26	12	9	21	21
		Total	1075	1249	1306	1132	970

Next Steps

If you are concerned about arsenic, check out the Purdex website to see if it has been detected in your water and how much might be present. The good news is that arsenic can be removed from drinking water with the installation of a home filtration system. There are many different types of filtration systems on the market and many of them do not remove arsenic, so you must be careful to choose the right one. The most critical part of your investigation is to determine the type of arsenic present in your water, arsenite (AsIII) and/or arsenate (AsV), because most home filtration systems will only remove arsenate, leaving arsenite in your water. Public water systems generally test for the presence of total arsenic without differentiating between the two forms, but check with your water department to see if they have any data available. You can also consider using a state-certified lab to analyze your water; it's a relatively inexpensive test and would give you the most reliable results.

If all else fails, bottled water is always an option. (Click here to check out the Purdex ratings for the top bottled water products.)

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