Environmental Assessment and Risk Analysis Element

Research Project Summary

July 2002

Arsenic and Mercury in Residential Well Water from Readington and Raritan Townships, Hunterdon County, New Jersey

Eileen A. Murphy, Ph.D.[1]

Abstract

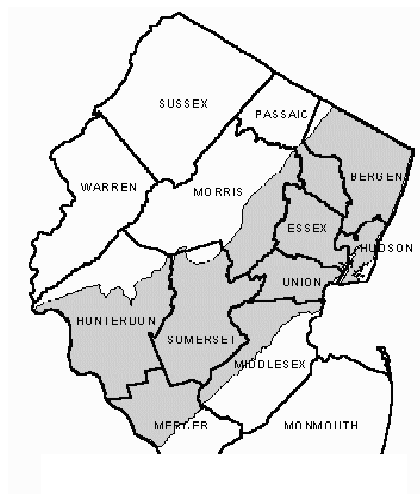
In October 2000, well water testing for arsenic and mercury was offered to residents living in Readington and Raritan Townships in Hunterdon County, New Jersey. The goal was to generate data on levels of these contaminants in ground water used for drinking water in the area. Previous testing showed that this part of the state may have potentially elevated levels of arsenic in well water due to leaching from certain arsenic-rich geologic formations. Two hundred thirty-eight wells were sampled. Three quarters of the well water samples contained arsenic levels below 5 µg/L (micrograms per liter). A quarter of the samples were above 5 µg/L, with 3% of wells containing arsenic levels above 10 µg/L. The highest arsenic level observed in this study was 35 µg/L. Few water samples had detectable levels of mercury, and of those where mercury was detected, the levels were trace.

Introduction

Arsenic (As) is a naturally-occurring element in the earth's crust, and traces of arsenic can be found throughout the environment. Historically, the heaviest use of arsenic in this country has been as a pesticide. The current predominant use of arsenic is as a wood preservative. In ground water, arsenic occurs primarily in two forms, As^{+3} (arsenite) and As^{+5} (arsenate). Arsenic may change chemical form in the environment, but it does not degrade. Organic arsenicals are not known to occur at significant levels in ground water.

Inorganic arsenic exists naturally at various levels in all geologic formations in the state. In some of these formations, arsenic is relatively immobile despite being present at high concentrations. In other formations, the chemical and physical properties of the geologic material may enable the arsenic to become mobile. Such conditions exist in rocks formed from organic-rich, ancient lake beds in a group of geologic formations in the Piedmont Physiographic Province of New Jersey, shown as the shaded area on the map in Figure 1. Results from a research project conducted by the New Jersey Geological Survey (NJGS) of the NJDEP's Division of Science, Research and Technology (DSRT) indicate that elevated levels of arsenic can exist in some aquifers of the Piedmont Province, particularly in the western portion. In that study, arsenic was detected in the western Piedmont at levels above 10 µg/L, or parts per billion (ppb), in the drinking water of 14 out of 91 homes sampled (15%), with one well showing arsenic at 57 µg/L. Based on that work, which included part of Hunterdon County, DSRT initiated the intensive sampling effort described here in order to determine general arsenic levels in domestic wells in a geographic area, specifically, Readington and Raritan Townships. Mercury was included as an analyte because of the scarcity of data on mercury levels in northwestern NJ. There are no known natural or anthropogenic source of mercury to ground water in the area.

Figure 1. Piedmont Physiographic Province (Shaded area)



Drinking Water Standard

Ingestion of large amounts of inorganic arsenic is associated with increased risk of several types of cancer in humans including skin, lung, liver, kidney, and bladder. The evidence for these cancers comes from studies in Taiwan, Bangladesh, Chile and Argentina where human populations were exposed to very high levels of inorganic arsenic through their drinking water. Other potential effects of ingestion of elevated arsenic include gastrointestinal complaints, such as diarrhea and cramping, thickening and/or discoloration of the skin, increased risk of diabetes and cardiovascular problems.

The carcinogenicity (or cancer-causing characteristics) of arsenic is difficult to study because it does not consistently induce cancer in laboratory animals, yet it is a known human carcinogen. It has been shown, in fact, to be an essential nutrient in several animal species, but it is unknown whether it may be an essential element in extremely small amounts for humans as well.

The current federal maximum contaminant level (MCL) for arsenic of 50 micrograms per liter (µg/L), or parts per billion (ppb), in drinking water was established in 1986 by the U.S. Environmental Protection Agency (USEPA) and was based on a U.S. Public Health Service standard originally established in 1942. Before 1986, an interim standard of 50 µg/L for arsenic was in effect. The final arsenic standard was scheduled to be updated with a series of other contaminants in 1991. However, due to newer evidence of human health effects of arsenic, the final MCL was delayed while the additional research results could be reviewed.

A March 1999 report by the National Academy of Sciences concluded that the current arsenic standard does not achieve USEPA's goal of protecting public health and should be lowered as soon as possible. On June 22, 2000, USEPA proposed a new drinking water standard of 5 µg/L for arsenic and requested comments on options of 3 µg/L, 10 µg/L and 20 µg/L . USEPA evaluated over 6,500 pages of comments from 1,100 commenters. On October 31, 2001, USEPA announced the arsenic standard for drinking water at 10 µg/L, effective on February 22, 2002; however, water system compliance is not required until 2006. New Jersey will adopt this standard by reference or may, through the action of the state's Drinking Water Quality Institute, select a more stringent arsenic standard.

The new federal arsenic standard of 10 µg/L will apply to all 54,000 community water systems in the country. A community water system is a system that serves 15 locations or 25 residents year-round, including most cities and towns, apartments, and mobile home parks with their own water supplies. USEPA estimates that roughly five percent, or 3,000, of community water systems, serving 11 million people, will have to take corrective action to lower the current levels of arsenic in their drinking water.

The new standard will also apply to 20,000 water systems that serve at least 25 of the same people more than six months of the year, such as schools, churches, nursing homes, and factories. USEPA estimates that five percent, or 1,100, of these water systems, serving approximately 2 million people, will need to take measures to meet the new arsenic standard. Of all of the affected systems, 97 percent are small systems that serve fewer than 10,000 people each.

The implementation deadline for compliance with the new standard is January 2006. In New Jersey, NJDEP regulators are proposing to lessen the time for the new arsenic standard to go into effect. Rather than waiting until January 2006 for compliance, the proposal calls for a 2004 compliance deadline.

At the time of this writing, the federal and state maximum contaminant level (MCL) of 10 µg/L for arsenic is scheduled to go into effect nationally on February 22, 2001, with compliance by January 2006 federally. It is possible that NJ may set its own standard lower than 10.

The MCL for mercury is 2 µg/L and is based on ingestion of inorganic mercury. EPA has found mercury to potentially cause kidney damage, and the MCL is based on this health end point.

Methods

Plastic water bottles with sampling instructions were made available to residents with private wells living in Readington and Raritan Townships in Hunterdon County, NJ. The effort was coordinated by the South Branch Watershed Association with the Environmental Commissions from the two townships. These groups offer annual well water testing to residents by arranging transportation of water samples from a central collection point in the townships to the laboratory. The residents are required to pay for any analysis they are interested in conducting on their well water. The groups agreed to allow NJDEP to offer free testing for arsenic and mercury through this existing annual program. There were three dates in each township during which residents were asked to collect their samples and deliver them to the investigator who, in turn, delivered them to the NJ Department of Health and Senior Services analytical laboratory for analysis of arsenic and mercury, using conventional USEPA analytical methods (graphic furnace atomic absorption spectroscopy for arsenic and cold vapor atomic absorption spectroscopy for mercury). The method detection limits for these analytes were 1 µg/L for arsenic and 0.04 µg/L for mercury. A method detection limit defines how close to zero the analytical technique is capable of measuring reliably and consistently.

To assure analytical quality, duplicate and blank samples were also collected by the investigator.

Homeowners were instructed to collect water samples before any type of water treatment, if possible. If it were not possible to do this, they were to indicate that the water had undergone treatment on the questionnaire provided. In one instance, a sample was collected before and after a water treatment system (reverse osmosis) in order to measure the system's effectiveness of removing arsenic. Although the system was not installed specifically to remove arsenic, reverse osmosis is one of the treatment methods recommended for arsenic removal. It was of interest to the investigator to determine the efficacy of the reverse osmosis system for arsenic removal.

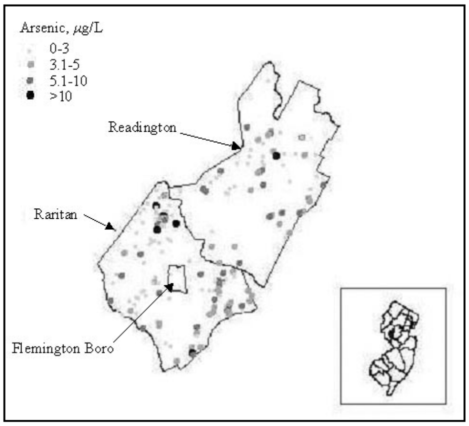
Participants were further instructed to allow the water to run for 15 minutes or to collect their water samples after showering, washing dishes, or similar water consumptive activity.

Results

All Data

Two hundred thirty-eight wells were sampled for mercury and arsenic in Raritan and Readington Townships, Hunterdon County. An additional 10 samples were analyzed as trip, blank and duplicate samples for quality assurance purposes. Some trip blank samples contained trace levels of mercury. After correcting the appropriate sampling results to account for the blank contamination, it was observed that only 19 water samples had detectable levels of mercury (detection limit was 0.04 μg/L, and the MCL is 2.0 μg/L), with the highest level being 0.08 μg/L.

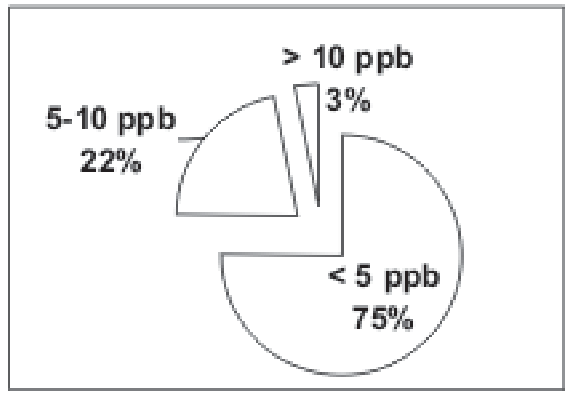
Figure 2. Geographic Distribution of Arsenic in Readington and Raritan Township, Hunterdon County, NJ



There was no observable blank contamination for arsenic. All of the well water samples contained arsenic levels below the current federal maximum contaminant level (MCL) of 50 μg/L. However, in October 2001 the federal and, by reference, state MCL for arsenic was set at 10 μg/L by USEPA to go into effect on February 22, 2002. There is a possibility that NJ may set the standard even lower in the future. Private well owners are not responsible by law for meeting drinking water standards in general; however, the state uses the drinking water MCLs as guidance levels in interpreting private well data. Therefore, for informational purposes, data are further distributed and presented in Table 1 for levels at 5 μg/L as well as 10 μg/L. The geographic distribution is displayed on the map in Figure 2. The overall arsenic distribution for the well water sampled as part of this study is displayed on the pie chart in Figure 3. Most of the arsenic levels were below 5 μg/L. A quarter of the samples were above 5 μg/L, with 3% of wells containing arsenic levels above 10 μg/L. The highest level was 35.3 μg/L. The home where the highest arsenic level was seen in well water had the reverse osmosis treatment system in place. A second sample collected after the water treatment showed no detectable levels of arsenic, indicating that reverse osmosis is effective in removing arsenic to levels well below the current and pending arsenic drinking water standards. In general, the data are not normally distributed, so nonparametric statistical analyses were done to look for differences in populations and to examine potential correlations among variables and the data.

Of the 238 wells sampled, well depth information was available for 143. Descriptive statistics for arsenic levels according to well depth for these wells are shown in Table 2. Mann-Whitney U testing for median differences for nonparametric populations shows that arsenic concentrations from wells greater than 300 ft. were significantly lower than those from wells between 101-300 ft. This distribution by well depth may indicate a geologic origin of the arsenic.

Figure 3. Distribution of Arsenic Concentrations in Well Water in Readington & Raritan.



Additional parameters that were examined in order to determine if there were any patterns in the data set included: the date that the house was constructed, whether water treatment was present in the house (usually water softeners), the spigot where the sample was collected, and whether the well or well pump had ever been replaced. No patterns were observed between arsenic levels and water treatment or between arsenic levels and well pump replacement. Some interesting patterns were observed for some of the other variables. For instance, arsenic concentrations in water samples collected from a basement fixture were significantly lower than water samples collected from elsewhere in the house (see graph in Figure 4 and data in Tables 3 and 4). This is a pattern that has been observed with lead, which may contaminate drinking water from dissolution of lead-bearing plumbing fixtures. Very small amounts of arsenic are known to be present in brass fixtures. The addition of a small amount of arsenic (typically 0.1%) to alpha brass alloys produces a dezincification-resistant brass frequently used for water fittings. Previous work by NJDEP on lead in household drinking water showed trace levels of arsenic (below 0.5 μg/L) occurring in water samples where lead levels were elevated. These arsenic concentrations were statistically positively correlated with the lead and copper levels. To look further into this issue, the arsenic data were reassessed after eliminating data points where arsenic levels were above 5 μg/L.

Arsenic data below 5 μg/L

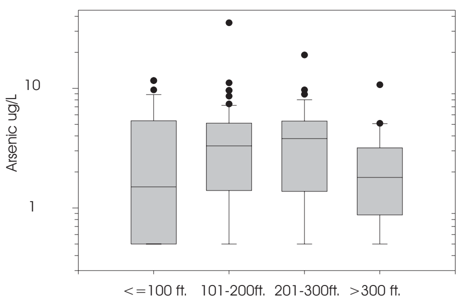
When the higher arsenic levels are removed from the data set, certain factors become more apparent. For instance, for data less than 5 μg/L, arsenic levels in water samples collected from the basement taps are all significantly lower than arsenic levels in water collected from a different tap. This is a pattern that has been observed for lead; lead levels increase as the water is afforded contact with more plumbing materials. Also, arsenic levels (regardless of tap sampled) were significantly higher from homes constructed after 1970 than homes constructed between 1900 and 1970 (Table 4). Arsenic is currently added (in trace amounts) to brass, so it is not surprising that there is no difference between the newer homes (constructed after 1990) and the older homes (constructed between 1971 and 1990). It is not known when the practice of adding arsenic to brass first began.

Further study is warranted to investigate the potential contribution of brass fixtures to arsenic (at very low levels) in drinking water. Whereas the largest contributor of arsenic to the water in this study is believed to be natural geologic materials, the contribution from plumbing materials may become significant as regulators consider lowering the arsenic standard further.

water tested for arsenic.

A new private well testing law has been passed in NJ. The bill will require statewide testing of water from private wells upon the sale of a home and will use the drinking water MCLs as guidance for interpreting the well water data generated as a result of the law. While arsenic is not included in the statewide testing requirements, it may be included in counties where prior regional testing has shown it to occur in well water. It has been recommended that arsenic be included for testing as part of the requirements for this bill in Bergen, Essex, Hunterdon, Mercer, Middlesex, Somerset, and Union Counties.

Figure 4. Arsenic levels according to depth of well sampled.



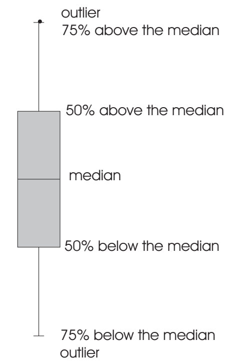


Figure 5. Arsenic data according to tap sampled.

Conclusions and Recommendations

While most of the water samples collected showed arsenic levels below 5 µg/L, 25% had levels above this. Depending upon where New Jersey sets its drinking water standard for arsenic, there could be 25% (if the standard is set at 5 µg/L) of wells in Readington and Raritan Townships exceeding the standard or 3% (if the standard is set at 10 µg/L). It is important for NJDEP to investigate water treatment options for those residents whose arsenic levels are elevated. Toward this end, an arsenic removal study for private wells was initiated by DSRT in the western Piedmont area. Results of the treatment study are not yet available. Reverse osmosis is known to be effective at removing arsenic from drinking water, and this was demonstrated from one home in this study. However, reverse osmosis wastes a great deal of water, is relatively difficult to maintain, and is expensive for a whole-house system. Currently, the Department recommends that residents whose well water exceeds 10 µg/L install a kitchen sink-mounted reverse osmosis system rather than a whole-house system for these reasons.

Whatever the standard, NJDEP, based on previous DSRT investigations and the results of this targeted study, maintains its current recommendation to residents in the Piedmont Region of the state to have their private well

For those seeking additional information about testing their well water for arsenic, there is a Homeowner's Guide to Arsenic in Drinking Water available on the NJDEP/DSRT website (www.state.nj.us/dep/dsr) or by contacting this office by phone at (609) 984-6070.

Prepared By
Eileen A. Murphy, Ph.D.

Acknowledgements: To Gary Buchanan, Ph.D., who assisted with the sampling; J. Michael Pollock, Executive Director of the South Branch Watershed Association, for coordinating the well sampling events; and to Mike Serfes, Steve Spayd, Marty Rosen and Judy Louis, Ph.D. for reviewing the document.

Acronyms

USEPA: U.S. Environmental Protection Agency
NJDEP: N.J. Department of Environmental Protection
DSRT: Division of Science, Research & Technology
NJGS: NJ Geological Survey
MCL: Maximum Contaminant Level
ppb: part per billion
µg/L: microgram per liter (equivalent to a ppb)

Table 1. Distribution of arsenic concentrations in well water.

Variable, µg/L	All Data	Wells with depth info.	< 100 ft.	101-200 ft.	201-300 ft.	> 300 ft.
N*	238	143	28	65	33	17
# wells < 5 µg/L	179 (75%)	105 (73%)	20 (71%)	48 (74%)	22 (67%)	15 (88%)
# wells > 5 µg/L	59 (25%)	38 (26%)	8 (29%)	17 (26%)	11 (33%)	2 (22%)
# wells > 10 µg/L	7 (3%)	5 (3%)	1 (4%)	2 (3%)	1 (3%)	1 (6%)

** N=Number of samples*

Table 2. Descriptive statistics (in µg/L) for arsenic levels according to well depth (data in parenthesis represents arsenic levels below 5 µg/L).

Variable, µg/L	ALL DATA	Wells with depth info.	< 100 ft.	101-200 ft.	201-300 ft.	> 300 ft.
N	238	143 (96)	28 (20)	65 (48)	33 (22)	17 (15)
Median	2.85	2.70 (1.9)	1.5 ab*(<1)	3.3b (2.2)	3.8b (1.85)	1.8a (1.20)
Minimum	< 1	< 1 (<1)	< 1 (<1)	< 1 (<1)	< 1 (<1)	< 1 (<1)
Maximum	35.3	35.3 (4.9)	11.6 (4.9)	35.3 (4.9)	19 (4.4)	10.7 (4.9)
25th percentile	1.1	< 1 (<1)	< 1 (<1)	1.4 (<1)	1.4 (1.1)	<1 (<1)
75th percentile	4.9	5.10 (3.55)	5.38 (2.0)	5.1 (3.75)	5.2 (3.8)	2.8 (2.5)
Arithmetic mean	3.56	3.68 (2.14)	3.19 (1.35)	3.99 (2.34)	4.08 (2.15)	2.51 (1.79)
Geometric mean	2.28	2.25 (1.55)	1.65 (<1)	2.52 (1.71)	2.73 (1.66)	1.66 (1.35)
Mode	< 1	< 1(<1)	< 1 (<1)	< 1 (<1)	< 1 (<1)	< 1 (<1)
Frequency of	55 (23%)	36 (25%)	13 (46%)	14 (22%)	5 (15%)	4 (24%)
mode		31 (32%)	13 (65%)	14 (29%)	5 (23%)	4 (27%)

** Same letters in a group indicate that populations are statistically similar.*

Table 3. Descriptive statistics (in µg/L) for arsenic according to the tap used for sampling (values in parentheses are for statistics for arsenic data less than 5 µg/L).

Variable, µg/L	All taps	Kitchen	Basement	Bathroom	Laundry	Outside
N	224 (167)	143 (110)	15 (11)	20 (12)	28 (18)	18 (16)
Median	3.05 (2.0)	3.2abc* (2.05a)	1.3b (<1b)	4.6abc (2.35a)	2.95bc (1.95a)	1.65a (1.5a)
Minimum	<1 (<1)	<1 (<1)	<1 (<1)	<1 (<1)	<1 (<1)	<1 (<1)
Maximum	35.3 (4.9)	11.6 (4.9)	35.3 (4.7)	19 (4.9)	10.7 (4.9)	6.5 (4.5)
25th percentile	1.15 (<1)	1.1 (<1)	<1 (<1)	2.1 (<1)	1.7 (1.1)	1.2 (<1)
75th percentile	5.0 (3.6)	4.7 (3.7)	5.6 (1.4)	5.9 (4.5)	5.3 (2.6)	3.6 (2.85)
Arithmetic mean	3.65 (2.17)	3.52 (2.3)	4.64 (1.3)	4.89 (2.6)	3.76 (2.0)	1.9 (2.35)
Geometric mean	2.36 (1.60)	2.3 (1.68)	1.73 (<1)	3.3 (1.9)	2.69 (1.6)	1.71 (1.5)
Mode	1 (<1)	<1 (<1)	<1 (<1)	<1 (<1)	<1 (<1)	<1 (<1)
Frequency of	48 (48)	31 (22%)	6 (40%)	3 (15%)	4 (14%)	4 (22%)
mode		31 (28%)	6 (55%)	3 (25%)	4 (22%)	4 (25%)

** Same individual letters in a group indicate that those populations are statistically similar.*

Table 4. Descriptive statistics (in µg/L) for arsenic according to the year that the house was constructed (values in parentheses are for statistics for arsenic data less than 5 µg/L).

Variable	All wells	All dates	Before 1900	1900-1970	1971-1990	After 1990
N	238	225 (168)	15 (9)	62 (48)	90 (71)	58 (40)
Median	2.85	3.0 (2.0)	4.6a* (2.5ab)	1.80b (1.15b)	3.15a (2.1a)	3.95a (2.5a)
Minimum	< 1	< 1 (<1)	< 1 (<1)	< 1 (<1)	< 1 (<1)	< 1 (<1)
Maximum	35.3	35.3 (4.9)	9.6 (4.6)	9.2 (4.7)	35.3 (4.9)	11.1 (4.9)
25th percentile	1.1	1.1 (<1)	1.8 (<1)	< 1 (<1)	1.3 (1.0)	1.9 (1.2)
75th percentile	4.9	5.0 (3.6)	6.5 (3.6)	4.4 (2.3)	4.7 (3.8)	5.2 (4.1)
Arithmetic mean	3.56	3.61 (2.17)	4.48 (2.4)	2.80 (1.56)	3.71 (2.33)	4.10 (2.57)
Geometric mean	2.28	2.33 (1.59)	3.08 (1.7)	1.68 (1.1)	2.39 (1.8)	2.97 (2.0)
Mode	< 1	< 1 (<1)	< 1 (<1)	< 1 (<1)	< 1 (<1)	< 1 (<1)
Frequency of	55 (23%)	51 (23%)	3 (20%)	23 (37%)	17 (19%)	8 (14%)
mode		51 (30%)	3 (33%)	23 (48%)	17 (24%)	8 (20%)

[redacted] individual letter in a group indicates that those populations are statistically similar.

STATE OF NEW JERSEY
James E. McGreevey, Governor

Department of Environmental Protection
Bradley M. Campbell, Commissioner

Division of Science, Research & Technology
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Dr. Eileen Murphy, Assistant Director

Please send comments or requests to:
Division of Science, Research and Technology
P.O.Box 409, Trenton, NJ 08625
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RESEARCH PROJECT SUMMARY